

**ЖУРНАЛ
ОБЩЕЙ ХИМИИ**

Volume 29 No. 4

April 1959

JOURNAL OF

GENERAL CHEMISTRY

OF THE USSR

(ZHURNAL OBSHCHEI KHIMII)

IN ENGLISH TRANSLATION



CONSULTANTS BUREAU, INC.

SYNTHESES OF HETEROCYCLIC COMPOUNDS

Volumes 1 and 2 Edited by
A. L. MNDZHOIAN

TRANSLATED FROM RUSSIAN

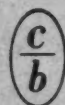
THE lack of a practical guide to the laboratory preparation of heterocyclic compounds is being met by this series of collections of synthesis methods, originally published by the Armenian Academy of Sciences.

The translation of Volumes 1 and 2 of this series is combined in this convenient handbook, devoted exclusively to the synthesis of furan derivatives.

Subsequent volumes in the series will be published in translation by Consultants Bureau promptly after their appearance in the original Russian.

1959 cloth 6 x 9 155 pp. illus. \$6.00

Book Division



CONSULTANTS BUREAU, INC.

227 WEST 17TH STREET, NEW YORK 11, N. Y.

Volume 29 No. 4

April 1959

JOURNAL OF
GENERAL CHEMISTRY
OF THE USSR

(ZHURNAL OBSHCHEI KHIMII)

A publication of the Academy of Sciences of the USSR

IN ENGLISH TRANSLATION

Year and issue of first translation:

Vol. 19, No. 1 January 1949

	<i>U. S. and Canada</i>	<i>Foreign</i>
<i>Annual subscription</i>	<i>\$90.00</i>	<i>\$95.00</i>
<i>Annual subscription for libraries of nonprofit academic institutions</i>	<i>30.00</i>	<i>35.00</i>
<i>Single issue</i>	<i>10.00</i>	<i>10.00</i>

Copyright 1960

CONSULTANTS BUREAU ENTERPRISES, INC.

227 West 17th Street, New York, N. Y.

JOURNAL OF GENERAL CHEMISTRY

OF THE USSR

(formerly JOURNAL OF INORGANIC CHEMISTRY)

Volume 35, No. 1, 1980

ISSN 0013-788X

Editorial Board

(ZHURNAL OBSHCHEI KHIMII)

A. E. Arbuzov, E. D. Venus-Danilova, S. N. Danilov (Editor-in-
Chief), A. N. Zakharova (Secretary), E. D. Kaverzneva,
M. A. Klochko, K. P. Mishchenko, A. A. Petrov,
B. V. Ptitsyn, S. A. Shchukarev, Iu. K. Iur'ev

*Note: The sale of photostatic copies of any
portion of this copyright translation is expressly
prohibited by the copyright owners.*

Printed in the United States of America

CONTENTS

	PAGE	RUSS. PAGE
Enthalpy of Formation of Niobium Oxides. <u>M. P. Morozova and L. I. Getskina</u>	1019	1049
The Value of the $\text{Co}^{3+}/\text{Co}^{2+}$ Oxidation-Reduction Potential, the Solubility Product of $\text{Co}(\text{OH})_3$ and the Relation Between These Values. <u>V. L. Khelfits, A. L. Rominyan, and E. S. Kozich</u>	1023	1052
Synthesis of Hydrocarbons. 68. C_{13} - C_{15} Ditertiary-Alkylmethanes From 3,5-Dimethylheptadiene-2,4. <u>R. Ya. Levina, V. K. Daukshas, and P. A. Kalkaris</u>	1026	1056
δ -Lactones. XVI. Synthesis of Aryl Substituted δ -Enol Lactones. <u>N. P. Shusherina, I. S. Trubnikov, and R. Ya. Levina</u>	1032	1062
Dehydration of 1-Alkylcyclopentanols. <u>A. F. Platé and A. A. Mel'nikov</u>	1035	1064
Catalytic Reactions in the Presence of Aluminum Metal. IV. Alkylation of Bromobenzene with Ethyl Bromide, n-Propyl Bromide and n-Butyl Bromide. Alkylation of Iodobenzene with n-Butyl Bromide. <u>M. B. Turova-Polyak and N. P. Dobrosel'skaya</u>	1043	1072
Isomerization of Polymethylene Hydrocarbons under the Action of Aluminum Chloride. XXIII. Isomerization of 2-Methyl-bicyclo-(1,2,2)-Heptane. <u>M. B. Turova-Polyak, I. E. Sosnina, I. G. Golutvina, and T. P. Yudkina</u>	1048	1078
Ethylene Sulfide in the Synthesis of Heterocyclic Compounds with Two Hetero Atoms. IX. Synthesis of 2-Acyl-3-Arylthiazolidines. <u>Yu. K. Yur'ev and S. V. Dyatlovitskaya</u>	1053	1083
Chemistry of Selenophene. XVI. 4- and 5-Nitroselenophene-2-aldehyde and the Synthesis of Isomeric Mononitroselenophenes. <u>Yu. K. Yur'ev and E. L. Zaitseva</u>	1057	1087
Hydrogenation of Furan Compounds on Platinum and Rhodium Catalysts. <u>N. I. Shuikin and I. F. Bel'skii</u>	1063	1093
Catalytic Reduction of 2-Methyl-5-acetylfuran to 2-Methyl-5-ethylfuran. <u>N. I. Shuikin and I. F. Bel'skii</u>	1066	1096
Investigation of Pyrazoles. III. Addition of α, β -Unsaturated Compounds to Pyrazoles. <u>I. I. Grandberg and A. N. Kost</u>	1069	1099
Diene Hydrocarbons from Unsaturated Alcohols. III. Catalytic Decomposition of Allylcarbinol. <u>Yu. A. Gorin, V. S. Ivanov, T. G. Pushnova, and V. V. Zlatogurskaya</u>	1074	1104
Reactions of α - and β -Chloroethylethyldichlorosilanes with Silicon under Direct Synthesis Conditions. <u>S. I. Sadykh-zade and A. D. Petrov</u>	1079	1109
Stereochemistry of Nitrogen Heterocycles. III. Stereoisomerism of 2-Methyl-4-Ketodecahydroquinoline. <u>D. V. Sokolov, G. S. Litvinenko, and K. I. Khudneva</u>	1083	1112
Polyene Synthesis. 2-Methyl-3-Phytylnaphthoquinone-1,4 - Vitamin K_1 . <u>I. K. Sarycheva, Yu. G. Molotkovskii, G. A. Vorob'eva, and N. A. Preobrazhenskii</u>	1092	1123

CONTENTS (continued)

	PAGE	RUSS. PAGE
The Reaction of Benzaldehyde and Cyclohexanone with Boric Esters. <u>V. K. Kuskov and A. N. Neverov</u>	1096	1127
Investigations in the Field of Quinoline and Its Derivatives. XXIII. New Method of Preparing Quinaldine Compounds and N-Arylquinaldinium Salts. <u>V. I. Minkin and B. I. Ardashev</u>	1099	1129
Some 2-Cyanoethyleneimines and Nitriles of α -Halo- β -Amino Acids. <u>V. K. Antonov</u> ..	1102	1132
Compounds with Potential Antitubercular Activity. I. Thioamides of Certain Thiazole-carboxylic acids. <u>T. P. Sycheva and I. V. Lebedeva</u>	1106	1135
Synthesis of Organophosphorus Compounds from Hydrocarbons and Their Derivatives. X. Oxidative Chlorophosphination of Certain Ethylene Derivatives. <u>L. Z. Soborovskii, Yu. M. Zinov'ev, and T. G. Spiridonova</u>	1110	1139
Difluorochloromethane as a Difluoromethylating Agent. I. Reaction of Difluorochloromethane with Sodium Alcoholates and Mercaptides. <u>L. Z. Soborovskii and N. F. Baina</u>	1113	1142
Difluorochloromethane as a Difluoromethylating Agent. II. Reaction of Difluorochloromethane with Sodium Dialkylphosphites. <u>L. Z. Soborovskii and N. F. Baina</u>	1115	1144
The Reformatsky Reaction with α -Halonitriles. III. Condensation of Methoxybenzaldehydes with Bromoacetonitrile. <u>N. S. Vul'fson and L. Kh. Vinograd</u>	1118	1147
Organic Insectofungicides. XLI. The Reaction of Dialkyl Chlorothiophosphates and Phosphorus Thiotrichloride with Phenols in the Presence of Tertiary Amines. <u>Ya. A. Mandel'baum, N. N. Mel'nikov, and Z. M. Bakanova</u>	1121	1149
Investigations in the Field of Conjugated Systems. XCVII. Addition of Alcohols to Vinylalkylacetylenes in the Presence of KOH. <u>B. S. Kupin and A. A. Petrov</u>	1123	1151
Diene Condensations of Gem-Substituted Butadienes. II. 1,1,2-Trimethylbutadiene. <u>I. N. Nazarov and M. V. Mavrov</u>	1130	1158
Diene Condensations of Gem-Substituted Butadienes. III. 1,1-Dimethyl-2-isopropylbutadiene. <u>I. N. Nazarov and M. V. Mavrov</u>	1139	1169
Synthesis of Analogs of Nerolidol, Farnesylacetone and Geranylinalool. <u>I. N. Nazarov, S. M. Makin, V. B. Mochalin, O. A. Shavrygina, and D. V. Nazarova</u>	1146	1176
Preparation of Monomercurated Ketones from Alkenes. <u>I. F. Lutsenko and R. I. Sivkova</u> ..	1152	1182
Sulfonic Esters of Cyclohexanediols and 1,4-Butanediol. <u>K. V. Levshina, A. K. Chizhov, Yu. N. Sheinker, and S. I. Sergievskaya</u>	1154	1184
Synthesis of 7-Cyano-2,6-dimethyl- and 2,3,6-Trimethylheptadienes-2,6, The Nitriles of Geranic and 3-Methylgeranic Acids. <u>I. K. Sarycheva, E. M. Shustorovich, G. A. Vorob'eva, and N. A. Preobrazhenskii</u>	1159	1189
Synthesis of the Dimethyl Ether of the Alkaloid (+)-Tubocurarine Iodide. <u>O. N. Tolkachev, V. G. Voronin, and N. A. Preobrazhenskii</u>	1163	1192
Investigation of Ethers with a Double Bond in the Allyl Position. IV. Preparation of Some Ethers of 2-Methyl-4-benzylpenten-2-ol-4 and 1-Phenylbuten-1-ol-3. <u>V. I. Pansevich-Kolyada and B. K. Bogush</u>	1168	1198

CONTENTS (continued)

	PAGE	RUSS. PAGE
Synthesis of Derivatives of Py-N-Benzyltetrahydronorharmine-3-carboxylic Acid. <u>L. N. Yakhontov and M. V. Rubtsov</u>	1172	1201
The Stereochemistry of the Symmetrization of Some Organomercury Derivatives of Camphor under the Action of Hydrazine Hydrate. <u>O. A. Reutov and Lu Ching-Chu</u>	1177	1207
The Transformation of Uric Acid into 8-Methylxanthine. III. Synthesis of Methylisocaffeine and the Structure of the Triacetyl Derivatives of 4,5-Diaminouracil. <u>E. S. Golovchinskaya</u>	1183	1213
A New Method of Synthesis of Esters of Phosphonic and Thiophosphonic Acids. XXX. The Reaction of Dialkylphosphorous and Dialkylthiophosphorous Acids with Ketene. <u>V. I. Nikitina and A. N. Pudovik</u>	1188	1219
The Reaction of Dialkylphosphorous Acids with Aldehydes and Ketones. XIX. Di-1-Trichloromethylcyclopentyl-1 Esters of α -Hydroxyalkylphosphonic Acids. <u>V. S. Abramov and V. K. Khairullin</u>	1192	1222
Hydroxy Derivatives of Anthracene. IV. 1-Nitroso-2-Anthrol-4-Sulfonic Acid and 2-Nitroso-1-anthrol-4-Sulfonic Acid. <u>S. V. Bogdanov and M. V. Gorelik</u>	1195	1225
Synthesis of α -Vinylhydroxybibenzyl. <u>B. I. Mikhant'ev and L. P. Pavlov</u>	1199	1230
Investigation of Mixed Ethylenic Acetylenic γ -Glycols. <u>A. I. Nogaideli, K. Ya. Dzagnidze, T. Pagava, and T. Kverenchkhiladze</u>	1201	1231
Reactions of Halonitroparaffins with Olefins. <u>Yu. A. Baskakov and N. N. Mel'nikov</u>	1204	1233
Jute Glycosides. II. The Structure of Olitoriside. <u>N. K. Abubakirov, V. A. Maslennikova, and M. B. Gorovits</u>	1206	1235
Arylamides of Dialkylaminoacetic Acids. <u>N. I. Kudryashova, A. L. Remizov, and N. V. Khromov-Borisov</u>	1211	1240
Salts of Alkylcarbonic Acids. IV. <u>V. I. Kurov</u>	1216	1245
Esters of N-Arylthiocarbamide-N'-Phosphoric Acids. <u>E. S. Levchenko and I. E. Sheinkman</u>	1221	1249
Organoboron Compounds. XXXIV. Alkylphenylboron Chlorides. <u>B. M. Mikhailov and P. M. Aronovich</u>	1226	1254
Organoboron Compounds. XXXV. Alkylphenylborinic Acids and Their Anhydrides. <u>B. M. Mikhailov and P. M. Aronovich</u>	1229	1257
On the Mechanism of Decomposition of 2-Phenylisopropyl[Isopropylbenzene]Hydroperoxide under the Influence of Ions of Metals of Variable Valence. <u>E. I. Tinyakova and T. G. Zhuravleva</u>	1234	1262
Polydiethylsiloxane Liquids. I. Action of Sulfuric Acid on Diethyldiethoxysilane and Its Mixtures with Triethylethoxysilane. <u>N. S. Leznov, L. A. Sabun, and K. A. Andrianov</u>	1241	1270
Polydiethylsiloxane Liquids. II. Action of Phosphoric and Boric Acids on Diethyldiethoxysilane and Mixtures of It with Triethylethoxysilane. <u>N. S. Leznov, L. A. Sabun and K. A. Andrianov</u>	1247	1276
Synthesis of Polymers with Inorganic Chains in the Molecules. I. Polyorganosiloxy-phosphoralumoxanes. <u>K. A. Andrianov, A. A. Zhdanov, and A. A. Kazakova</u>	1252	1281

CONTENTS (continued)

	PAGE	RUSS. PAGE
The Process of Polyamide Resin Formation. IX. A Contribution on the Alkaline Polymerization of ϵ -Caprolactam. <u>A. S. Shpital'nyi and M. A. Shpital'nyi</u>	1256	1285
Steric Hindrance in Quaternary Salts of 2-Arylbenzthiazoles, 2-Arylbenzimidazoles and 2-Arylpyridines. <u>A. I. Kiprianov and V. A. Shrubovich</u>	1261	1290
Arylphenazines. 2-Phenylphenazine and Its Derivatives. <u>Yu. S. Rosum</u>	1271	1299
The Directing Action of Substituents in the Formation of Phenazine N-Oxide. <u>Yu. S. Rosum and A. I. Kiprianov</u>	1278	1306
Cyanine Dyes Containing Fluorine. VI. Synthesis of Cyanine Dyes From 5-Trifluoromethoxy-6-Acetylamino benzthiazole. <u>L. M. Yagupol'skii</u>	1284	1312
The Absorption Spectra and Structure of Acyl Derivatives of 9-Aminoacridine. <u>A. K. Sukhomlinov and V. I. Bliznyukov</u>	1288	1316
Reaction of β -Chlorovinyl Ketones with β -Dicarbonyl Compounds. IX. Ketovinylation of Esters of Cyclic β -Keto Acids. <u>N. K. Kochetkov, B. P. Gottikh, and Rol'f Shtumpf</u>	1293	1320
Reaction of β -Chlorovinyl Ketones with β -Dicarbonyl Compounds. X. Preparation of α -Pyrone Derivatives from α -(3-Ketoalkenyl-1)- β -Keto Acids. <u>N. K. Kochetkov and B. P. Gottikh</u>	1297	1324
Cycloserine and Related Compounds. VII. Synthesis of 5-Methyl-4-Aminoisoxazolidone-3 (Cyclothreonine). <u>R. M. Khomutov, M. Ya. Karpeiskii, E. I. Budovskii, E. S. Severin, and N. K. Kochetkov</u>	1302	1328
Synthesis of Some Formazans, Thiohydrazides and Thiadiazolines with a Carbohydrate Residue. <u>I. Ya. Postovskii and M. I. Ermakova</u>	1307	1333
Alkylation of 4-Bromophenol with Propylene and β -Amylene in the Presence of $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ and $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ Catalysts. <u>S. V. Zavgorodnii and V. G. Kryuchkova</u>	1315	1340
Investigation in the Anthraquinone Series. XXVII. The Hydrolysis of 1,5- and 1,8-Nitrosulfonic Acids of Anthraquinone (1,5- and 1,8-Nitrohydroxyanthraquinones). <u>V. V. Kozlov</u>	1319	1344
Interaction of 6-Chloromethylquinoline with Amines. <u>B. P. Lugovkin</u>	1325	1350
Catalytic Reduction of Haloalkyl-Substituted Aromatic Nitro Compounds. <u>V. M. Berezovskii and Yu. P. Sobolev</u>	1329	1353
Some New Acid Amides - Plant Growth Regulators. <u>K. S. Bokarev</u>	1334	1358
Reduction of Derivatives of α, β -Unsaturated Acids on the Dropping Mercury Cathode. I. Derivatives of Fumaric Acid. <u>I. A. Korshunov, Yu. V. Vodzinskii, N. S. Vyazankin and A. I. Kalinin</u>	1340	1364
Polarographic Study of Anthraquinone Compounds and Their Tetra- and Octahydro Derivatives. <u>V. E. Ditsent</u>	1346	1370
Physicochemical Study of the Reaction of Zirconium Chloride with Esters of Monobasic Acids. III. <u>O. A. Osipov and Yu. B. Kletenik</u>	1351	1375
Physicochemical Study of the Structure and the Properties of the Oxygen Compounds of Nickel. <u>D. P. Bogatskii and I. A. Mineeva</u>	1358	1382

CONTENTS (continued)

	PAGE	RUSS. PAGE
Regularities in Properties of Thallium. <u>I. M. Korenman</u>	1366	1390
Effect of Some Electrolytes on Solubility of Benzoic Acid in Water. <u>V. F. Sergeeva and M. I. Usanovich</u>	1369	1393
Letters to the Editor		
Spectral Study of Aromatic Diazo Compounds. <u>B. A. Porai-Koshits and B. V. Passet...</u>	1373	1397
Concerning a Rational Method of Expressing Composition in the Study of Densities of Solutions. <u>V. A. Mikhailov and A. A. Kamarzin</u>	1375	1398
Concerning the Errors of the "Method of the Fourth Component". <u>V. F. Boiko..</u>	1377	1400
Erratum	1378A	

CONTENTS

PAGE

1. Introduction	1
2. Theoretical Framework	10
3. Methodology	25
4. Results	45
5. Discussion	65
6. Conclusion	85
7. References	95
8. Appendix	105
9. Index	115

ENTHALPY OF FORMATION OF NIOBIUM OXIDES

M. P. Morozova and L. L. Getskina

Leningrad State University

Of the three compounds existing in the Nb-O system, two, Nb_2O_5 and NbO_2 , have been characterized thermochemically; the enthalpy of formation of the lowest oxide, NbO , has only been evaluated by Evans and Kubashevsky [1] and apparently has not been determined experimentally.

We found the enthalpies of formation of niobium oxides by determining the heats of combustion of niobium metal, NbO and NbO_2 in a precision vacuum calorimeter, similar in construction to the calorimeter described by Magnus [2]. The combustion bomb (weight about 25 kg), made from pure copper, was suspended inside a steel cylinder with a ground lid, in which a vacuum of the order of 10^{-3} mm could be attained. The internal surface of the bomb was gilded and the external one plated with nickel to prevent corrosion and to decrease heat exchange by radiation. The bomb had a hole drilled in it, into which was fused an MMT-4 thermal resistance by means of a low-melting alloy. The resistance of the "thermistor" was measured by means of a Wheatstone bridge with a GEC-47 mirror galvanometer as a null instrument. The steel cylinder with the bomb was set in a water thermostat of about 500 liters capacity and fitted with two stirrers and a heating spiral. During the course of the experiment, the temperature of the thermostat was kept constant with an accuracy of up to 0.01° . Due to the vacuum in the casing of the calorimeter, the correction for heat exchange was a quite insignificant fraction of the total value of the change in the bomb temperature. All the calorimetric measurements were performed at 18° . The "water value" of the calorimeter was established from the heat of combustion of benzoic acid, prepared as a calorimetric standard by the All-Union Metrology and Standardization Scientific Research Institute in Leningrad.

The preparations were obtained by sintering mixtures of niobium metal and Nb_2O_5 at 1400° . The Nb_2O_5 preparation was chemically pure grade; according to the maker's data, the niobium metal had the following composition (in %): Nb 98.5, Ta 0.5, Ti 0.04, Fe 0.06, Si 0.04, Pb 0.15, C 0.12. The total of the given components is 99.41%. We regarded the other 0.59% as being due to the presence of oxygen in the preparation.

The oxygen pressure in the calorimetric experiments was 35 kg/cm^2 . Niobium dioxide was oxidized quantitatively to Nb_2O_5 under these conditions with its combustion initiated by the burning of an iron wire. As regards NbO and metallic niobium, under these conditions they formed a fused product, containing incompletely oxidized material inside it. Complete oxidation could not be achieved either by changing the oxygen pressure or by adding benzoic acid to these substances. Therefore, metallic niobium was combusted as a mixture with Nb_2O_5 and NbO as a mixture with NbO_2 .

The results obtained in the combustion of metallic niobium are presented in Table 1, in which the values of the heat effects given include all corrections (as in subsequent tables, also).

Considering that the niobium metal had 0.59% oxygen, we were virtually dealing with a preparation with the empirical composition $\text{NbO}_{0.035}$. Assuming that the enthalpy of formation of niobium oxides in the range Nb- $\text{NbO}_{2.5}$ is a linear function of composition, we introduced an appropriate correction into the value found directly. The values obtained with the inclusion of this corrections and also allowing for 0.5% of tantalum impurity are presented in the last column of Table 1.

TABLE 1

Sample of niobium metal	Sample of Nb_2O_5	$-\Delta\text{H}$ of combustion (kcal/g formula of $\text{NbO}_{2.5}$)	$-\Delta\text{H}$ of combustion allowing for the presence of oxygen and tantalum in the niobium metal (kcal/g formula of $\text{NbO}_{2.5}$)
0.54029	0.21282	233.00	236.9
0.54042	0.21266	233.1	236.1
0.54200	0.21090	234.1	235.8
Average . . .		233.4 ± 0.5	236.3

Thus, we consider that -236.3 ± 0.5 kcal/g-formula is the most probable value of the enthalpy of formation of $\text{NbO}_{2.5}$.



In 1933, Becker and Roth [3] found 231.6 kcal/g-formula for the heat of combustion of niobium to $\text{NbO}_{2.5}$; Kubashevsky and Evans [1] evaluated the error of this value as ± 4 kcal. Humphrey [4] found a considerably lower value for the enthalpy of combustion of niobium to $\text{NbO}_{2.5}$, namely -227.6 kcal. Previously [5], we determined the enthalpy of combustion of titanium oxides and we obtained data which practically coincided with the data of Humphrey [6]. Thus, the reason for the discrepancy in the case of the enthalpy of formation of $\text{NbO}_{2.5}$ is evidently not the difference in procedure, but in the substances used. It seems somewhat strange that Humphrey considered that he was using niobium sheet completely free from oxygen (he introduced a correction only for metallic impurities, determined by spectral analysis).

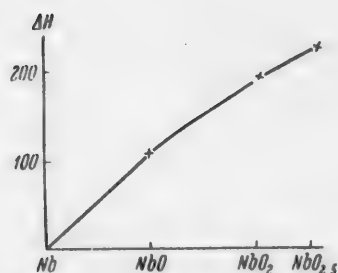
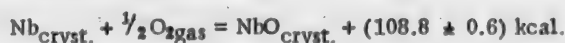
TABLE 2

Sample		$-\Delta\text{H}$ of combustion of NbO	$-\Delta\text{H}$ of combustion, allowing for the presence of tantalum
NbO	NbO_2		
0.94876	0.49684	127.3	126.9
0.92090	0.50250	128.4	127.6
0.934141	0.50562	128.8	128.0
Average . . .		128.2 ± 0.6	127.5

The niobium monoxide, NbO, we prepared had the composition $\text{NbO}_{1.001}$. In all cases, the combustion proceeded to the composition $\text{NbO}_{2.46}$, and in connection with, a correction of 2-2.5 kcal/g-formula was introduced into the results of the experiments to allow for the incompleteness of oxidation. The results of the experiments are presented in Table 2, the last column of which contains values corrected for the tantalum content of the preparation.

The correction was introduced on the assumption that the tantalum in the niobium monoxide preparation was present as the metal since, referred to 1 g-at. of oxygen, the heat of formation of niobium monoxide is greater than the corresponding value for Ta_2O_5 (we assume here that the Ta-O system contains only the compound Ta_2O_5 , since up to now there has been no conclusive evidence of the existence of lower oxides of tantalum).

The data in Table 2 give grounds for assuming that the enthalpy of formation of niobium monoxide has a value equal to -108.8 ± 0.6 kcal/g-formula:



Enthalpy of formation of niobium oxides as a function of their composition.

Kubashevsky and Evans [1] evaluated the enthalpy of formation of niobium monoxide as -116 ± 10 kcal/g-formula.

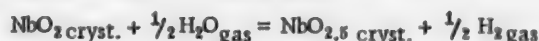
The values of the heat of combustion, obtained for niobium dioxide with the composition $\text{NbO}_{2.014}$, according to analysis, are presented in Table 3, where the last column contains values corrected for the tantalum content of the preparation.

In this case it was assumed that the tantalum was present as Ta_2O_5 , since, calculated on 1 g-at. of oxygen, the heat of oxidation of tantalum to its higher oxide is greater than the corresponding value for NbO_2 . As regards introducing the correction for the presence of tantalum in the preparation, it should be noted that for both the oxides of niobium, NbO and NbO_2 , it is less than the error of the calorimetric experiments.

Thus, we consider that it can be accepted that -199.3 ± 0.4 kcal/g-formula can be accepted for the enthalpy of formation of niobium dioxide at 18° :



On the basis of a study of the equilibrium of the reaction



Sue [7] put forward the value -193.5 kcal/g-formula for the enthalpy of formation of niobium dioxide. Kubashevsky and Evans estimated the error of this value as ± 5 kcal.

TABLE 3

Sample of NbO_2	$-\Delta H$ of combustion of NbO_2	$-\Delta H$ of combustion of NbO_2 , allowing for the presence of tantalum
0.93052	36.2	36.4
0.86408	37.0	37.2
0.86254	37.2	37.3
Average . . .	36.8 ± 0.4	37.0

The figure shows a plot of the enthalpy of formation of niobium oxides as a function of their composition. It is readily seen that the Nb-O system exhibits the usual succession of values - a decrease in the heat effect, relative to 1 g-at. of oxygen, as the amount of oxygen in the oxides increases. Niobium monoxide is characterized by a not completely closely packed structure and it crystallizes in a lattice of the NaCl type, though 25% of the positions in niobium and oxygen sublattices are vacant [8]. A large fraction (about 15%) of vacant positions also characterizes the TiO lattice; such "porousness" of structure must cause a decrease in the lattice energy. In the Ti-O system, the monoxide, TiO, has a heat of formation which is less than the heat of formation of the mixture $\text{TiO}_{0.48}$ (the upper stability limit of phase poorest in oxygen in the Ti-O system) and $\text{TiO}_{1.50}$ (following TiO in the direction of increasing oxygen for compounds in the Ti-O system), i.e., TiO is energetically unstable and only exists due to a relatively high entropy value. As the figure shows, in the case of NbO, the noncompactness of the structure does not show up to such a large extent in the plot of the enthalpy of formation of niobium oxides. It should be noted that there are some factors making NbO a stable compound since the elements adjacent to niobium, Zr and Mo, do not form thermodynamically stable oxides of this form.

SUMMARY

The enthalpies of formation of NbO , NbO_2 and $\text{NbO}_{2.5}$ were found and equal 108.8 ± 0.6 kcal, 199.3 ± 0.4 kcal and 236.3 ± 0.5 kcal, respectively (at 18°).

LITERATURE CITED

- [1] O. Kubashevsky and E. Evans. Thermochemistry in Metallurgy, Foreign Lit. Press (1954) [Russian translation].
- [2] Magnus, Z. phys. Ch., 196, 379 (1951).
- [3] G. Becker and W. A. Roth, Z. phys. Ch., (A), 167, 16 (1933).
- [4] G. L. Humphrey, J. Am. Chem. Soc., 76, 978 (1954).
- [5] M. P. Morozova, É. Vol'f and S. M. Ariya, Bull. Leningrad State University, No. 22, 91 (1956).
- [6] G. L. Humphrey, J. Am. Chem. Soc., 73, 1587 (1951).
- [7] P. Sue, C.R., 208, 1088 (1939).
- [8] G. Brauer, Z. anorg. allg. Ch., 248, 1 (1941).

Received March 10, 1958

THE VALUE OF THE $\text{Co}^{3+}/\text{Co}^{2+}$ OXIDATION-REDUCTION POTENTIAL,
THE SOLUBILITY PRODUCT OF $\text{Co}(\text{OH})_3$ AND THE RELATION
BETWEEN THESE VALUES

V. L. Kheifits, A. L. Rominyan and E. S. Kozich

Institute of the Nickel, Cobalt and Tin Industry, Leningrad

The standard value of the oxidation-reduction potential for the reaction $\text{Co}^{3+} + e = \text{Co}^{2+}$ quoted in the literature is usually from the data of Noyes and Deal [1] and equals +1.84 V. These authors measured the oxidizing potentials in 3N nitric acid at different ratios of $\text{Co}^{3+}/\text{Co}^{2+}$ and obtained values lying above the equilibrium oxygen potential under these conditions. In those cases where the equilibrium value of the oxidation-reduction potential lies above the oxygen potential, the direct determination of the oxidation-reduction potential is impossible in principle, since, practically, the compromise potential of the reaction $\text{Me}^{n+} + ze = \text{Me}^{(n-z)+}$ and $2\text{H}_2\text{O} - 4e = \text{O}_2 + 4\text{H}^+$ is measured. For this reason, the potential value of Noyes and Deal cannot be considered equilibrium and, consequently, the calculated value of the standard potential may be doubtful.

In exactly the same way, the solubility product of $\text{Co}(\text{OH})_3$ was found by direct determination. Actually, the value of the oxidation-reduction potential of $\text{Co}^{3+}/\text{Co}^{2+}$ is determined by the ratio of the activities of the tri- and divalent cobalt ions. In an attempt to determine the solubility product from the solubility of $\text{Co}(\text{OH})_3$ in water it is possible to avoid partial reduction of Co^{3+} to Co^{2+} to the activity ratio at which $\varphi_{\text{Co}^{3+}/\text{Co}^{2+}}$ coincides with the value of the oxygen potential. Under these conditions, the ratio $a_{\text{Co}^{3+}}/a_{\text{Co}^{2+}}$ will be determined by the value of the $\text{Co}^{3+}/\text{Co}^{2+}$ standard potential, which, as was noted above, is not accurately known. Thus, by measuring the concentration of cobalt ions in one solution at equilibrium between $\text{Co}(\text{OH})_3$ and water, we determine the total concentration of di- and trivalent ions and the solubility product calculated from this value is not accurate. It must be assumed that this circumstance led to the high value for the solubility product of the cobalt hydroxide ($S_{\text{PCo}(\text{OH})_3} = 2.8 \cdot 10^{-26}$) obtained by Cacciapuotti and Ferla [2] by means of radioactive cobalt. From thermodynamic data, W. Latimer [3] calculated the value of the solubility product as $2.5 \cdot 10^{-43}$. S. I. Sobol' [4], who put forward a series of considerations casting doubts on the starting data of Latimer, made an attempt to determine the solubility product of cobalt hydroxide from measurements of the oxidation-reduction potentials and the pH of the solution. As his data show, all the potentials he measured lay above the oxygen line and, consequently, in his experiments the system was not in equilibrium with water; therefore his calculations were incorrect and the value of the solubility product obtained, although close to the value given above, cannot be considered correct.

When the oxidation-reduction potential of an $\text{Me}^{n+}/\text{Me}^{(n-z)+}$ system is above the oxygen line and the higher hydroxide difficultly soluble, there is a functional relation between the value of the standard oxidation-reduction potential of the system and the solubility product of the higher hydroxide.

Let us examine this relation on the example of cobalt.

The value of the equilibrium potential of the reaction $\text{Co}^{3+} + e = \text{Co}^{2+}$ is determined by the Nernst - Peters formula

$$\varphi_{\text{Co}^{3+}/\text{Co}^{2+}} = \varphi_{\text{Co}^{3+}/\text{Co}^{2+}}^0 + \frac{2.3RT}{F} \lg \frac{a_{\text{Co}^{3+}}}{a_{\text{Co}^{2+}}} \quad (1)$$

But since the trivalent cobalt ions are decomposed by water, their concentration in equilibrium with water will be determined by the equation

$$\varphi_{\text{Co}^{3+}/\text{Co}^{2+}} = \varphi_{\text{O}_2} \quad (2)$$

From equations (1) and (2) we have:

$$\varphi_{\text{Co}^{3+}/\text{Co}^{2+}}^0 + \frac{2.3RT}{F} \lg \frac{a_{\text{Co}^{2+}}}{a_{\text{Co}^{3+}}} = \varphi_{\text{O}_2}^0 - \frac{2.3RT}{F} \text{pH}, \quad (3)$$

whence

$$\lg a_{\text{Co}^{2+}} = \frac{(\varphi_{\text{O}_2}^0 - \varphi_{\text{Co}^{3+}/\text{Co}^{2+}}^0) F}{2.3RT} - \text{pH} + \lg a_{\text{Co}^{3+}}. \quad (4)$$

On the other hand, if the solution is in equilibrium with a solid phase of $\text{Co}(\text{OH})_3$, then the concentration of trivalent cobalt ions will be determined by the solubility product also

$$S_{\text{p Co}(\text{OH})_3} = a_{\text{Co}^{3+}} a_{\text{OH}^-}^3 = a_{\text{Co}^{3+}} \frac{K_w^3}{a_{\text{H}^+}^3}, \quad (5)$$

whence

$$\lg a_{\text{Co}^{3+}} = \lg S_{\text{p Co}(\text{OH})_3} - 3 \lg K_w - 3 \text{pH}. \quad (6)$$

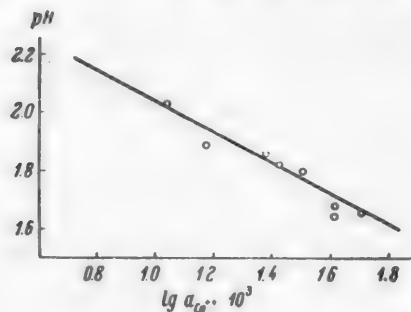
From (4) and (6) we obtain:

$$\frac{(\varphi_{\text{O}_2}^0 - \varphi_{\text{Co}^{3+}/\text{Co}^{2+}}^0) F}{2.3RT} - \text{pH} + \lg a_{\text{Co}^{2+}} = \lg S_{\text{p Co}(\text{OH})_3} - 3 \lg K_w - 3 \text{pH} \quad (7)$$

or

$$\begin{aligned} \varphi_{\text{Co}^{3+}/\text{Co}^{2+}}^0 = \varphi_{\text{O}_2}^0 - \frac{2.3RT}{F} \lg S_{\text{p Co}(\text{OH})_3} + \frac{6.9RT}{F} \lg K_w + \frac{4.6RT}{F} \text{pH} + \\ + \frac{2.3RT}{F} \lg a_{\text{Co}^{2+}}. \end{aligned} \quad (8)$$

From this equation it follows that the value of the oxidation-reduction potential depends not only on $\varphi_{\text{O}_2}^0$ and K_w , values which are known quite accurately, but also on the pH of the solution in equilibrium with the solid phase, the activity of the divalent cobalt ions and the solubility product of cobalt hydroxide.



To determine the equilibrium value of the pH of formation of cobaltic hydroxide, we prepared slightly acid solutions of CoSO_4 of various concentrations (activities) and equilibrated them (by prolonged shaking) with a solid phase of $\text{Co}(\text{OH})_3$. The pH of the liquid phase was measured with a glass electrode. The results of the measurements are illustrated in the figure, in which the average activity of CoSO_4 is plotted along the abscissa and the equilibrium pH value of the beginning of $\text{Co}(\text{OH})_3$ formation along the ordinate.

According to Equation (8),

$$-\frac{d \text{pH}}{d \lg a_{\text{Co}^{2+}}} = \frac{1}{2}. \quad (9)$$

From the data presented in the figure it is obvious that this relation is confirmed quite well by experiment (the solid line on the figure was drawn at the theoretical slope). Further, from the figure, it follows that at $a_{\text{CoSO}_4} = 1$ pH, the pH of the beginning of formation of a $\text{Co}(\text{OH})_3$ solid phase equals unity.

Thus, in Equation (8) two further interconnected values, $\varphi_{\text{Co}^{3+}/\text{Co}^{2+}}$ and $S_{\text{P Co}(\text{OH})_3}$, remain and can be compared.

If we consider that the solubility product obtained by Latimer is correct, then for the value of the standard oxidation-reduction potential we obtain $\varphi_{\text{Co}^{3+}/\text{Co}^{2+}}^0 = 1.23 + 0.06 \cdot 43 - 0.18 \cdot 13.9 + 0.12 = 1.45$ V.

However, if we carry out the calculation starting from the value $\varphi_{\text{Co}^{3+}/\text{Co}^{2+}} = 1.84$ V, then the solubility product of $\text{Co}(\text{OH})_3$ is found to be equal to approximately 10^{-50} , i.e., seven orders less than the value calculated by Latimer.

Sobol' considers that the calculation of Latimer, based on the heat of formation of the hydroxide obtained by Thompson (173 kcal/mole), is inaccurate, since this heat effect is low due to the fact that under the conditions of Thompson's experiments, the precipitation of not only $\text{Co}(\text{OH})_3$ is possible, but also partial entrainment of divalent cobalt ions in the precipitate in the form of $\text{Co}(\text{OH})_2$.

To obtain a value of $S_{\text{P Co}(\text{OH})_3} = 10^{-50}$, the heat of formation of the hydroxide must be of the order of 183 kcal/mole, i.e., exceed the value obtained by Thompson by a total of 6%. Considering the comments of Sobol', such an error in Thompson's measurement can be considered possible. It is much more difficult to determine the accuracy of the value of the standard oxidation-reduction potential. If Noyes and Deal measured the compromise potential, then probably the true value of the standard potential must be some value more electropositive than +1.84 V. This again indicates the inaccuracy of Latimer's calculation of the solubility product of cobalt hydroxide. However, if in the experiments of Noyes and Deal, any anodic oxidation products of nitric acid showed electromotive activity, then the measured values of the oxidation-reduction potentials could have been more electropositive than corresponds to the reaction $\text{Co}^{3+} + e = \text{Co}^{2+}$.

What has been stated above leads to the conclusion that it is necessary to determine the values of the standard oxidation-reduction potential of $\text{Co}^{3+}/\text{Co}^{2+}$ and the solubility product of cobalt hydroxide more accurately.

SUMMARY

1. An examination was made of the relation between the value of the standard oxidation-reduction potential of the system $\text{Me}^{\text{III}}/\text{Me}^{(\text{II}-Z)^+}$ and the solubility product of the higher hydroxide.
2. A study was made of the dependence of the equilibrium pH values in the system $\text{Co}(\text{OH})_3 - \text{CoSO}_4$ on the CoSO_4 activity and it was shown that in the coordinates $\text{pH} - \log a_{\pm \text{CoSO}_4}$, in agreement with theory, a straight line was obtained with a slope of 0.5. The pH value, corresponding to $a_{\text{CoSO}_4} = 1$, equal unity.
3. Possible errors in the determination of $\varphi_{\text{Co}^{3+}/\text{Co}^{2+}}$ and $S_{\text{P Co}(\text{OH})_3}$.

LITERATURE CITED

- [1] A. A. Noyes and T. I. Deal, J. Am. Chem. Soc., 39, 1337 (1937).
- [2] B. N. Cacciapuotti and F. Ferla, Atti Linc., 28, 385 (1938).
- [3] W. Latimer, Oxidation States of the Elements. Foreign Lit. Press (1954).
- [4] S. I. Sobol', J. Gen. Chem., 23, 906 (1953).

Received February 19, 1958

SYNTHESIS OF HYDROCARBONS

68. C₁₃-C₁₅ DITERTIARY-ALKYLMETHANES FROM 3,5-DIMETHYLHEPTADIENE-2,4

R. Ya. Levina, V. K. Daukshas and P. A. Kaikaris

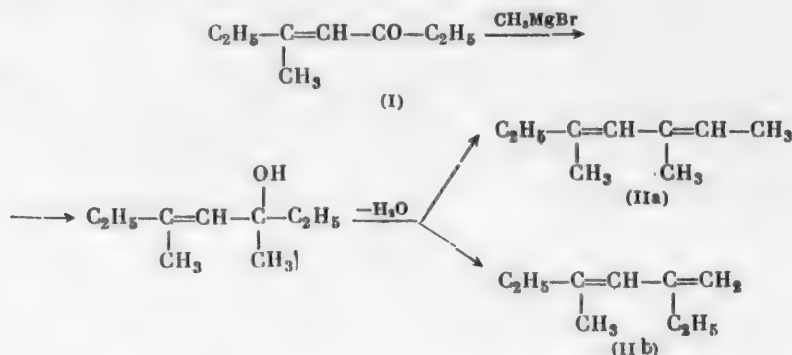
Moscow State University

In previous communications [1,2] a new method was described for the synthesis of ditertiary-alkylmethanes of the general structure $R'(CH_3)_2C-CH_2-C(CH_3)_2R$. The starting material for this synthesis was a tertiary chloride of the allyl type, obtained by the hydrochlorination of 2,4-dimethylpentadiene-1,3 and which does not form an isomeric chloride on allyl rearrangement. In the present work we synthesized ditertiary-alkylmethanes

of the structure* $R'-\overset{\overset{C_2H_5}{|}}{\underset{\underset{CH_3}{|}}{C}}-CH_2-\overset{\overset{C_2H_5}{|}}{\underset{\underset{CH_3}{|}}{C}}-R$ using the monohydrochloride of 3,5-dimethylheptadiene-2,4, which is

also a tertiary allyl chloride (III) that does not change its structure on allyl rearrangement.

The starting 3,5-dimethylheptadiene-2,4 (IIa) was synthesized by the action of methylmagnesium bromide on 3-methylhepten-3-one-5, the product of crotonic condensation of methyl ethyl ketone, the so-called "homomesitone A" (I) (proof of the structure of homomesitone A and the homomesitone B, isomeric with it, is given in the work of many authors [3-5]).

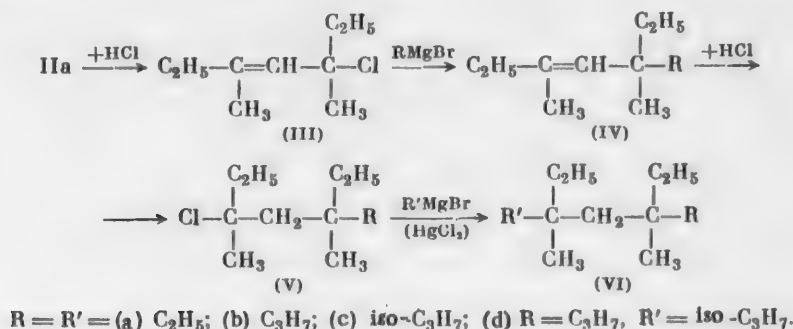


The 3,5-dimethylheptadiene-2,4 formed contained a trace of another diene hydrocarbon (IIb; 3-methyl-5-ethylhexadiene-3,5) with the same carbon skeleton but a different disposition of the double bonds; the mixture of dienes obtained was used for subsequent addition of hydrogen chloride since they both formed the same monohydrochloride (III), 3-chloro-3,5-dimethylheptene-4 [6].

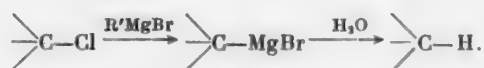
Reaction between the hydrochloride of 3,5-dimethylheptadiene-2,4 (III) and alkylmagnesium bromides

*Only the first member of this series of hydrocarbons (where $R = R' = CH_3$) has been described; we synthesized it previously [1] from the hydrochloride of 2,4-dimethylpentadiene-1,3 by the successive action of C_2H_5MgBr , HCl and again C_2H_5MgBr .

leads to the formation of ethylene hydrocarbons (IV) (in 40-50% yields*), which had one quaternary carbon atom (their structure was previously confirmed by oxidation [6]; hydrochlorination of the latter yielded (in about 90% yield) the saturated tertiary chlorides (V), which reacted with alkylmagnesium bromides in the presence of mercuric chloride (a catalyst for the Grignard-Wurtz reaction between RMgBr and tertiary chlorides [7, 8]) to form saturated hydrocarbons, containing two quaternary carbon atoms separated by a CH₂ group (di-tertiary-alkylmethanes of structure VI).



In the reaction of tertiary saturated chlorides (V) with R'MgBr there was not only replacement of chlorine by the radical of the organomagnesium compound, but also the side reaction of elimination of hydrogen chloride from the tertiary chlorides (V) with the formation (about 60%) of the original alkenes (IV). In each case, the mixture of alkanes (VI) and alkenes (IV) formed was readily separated by distillation on a column; after their hydrochlorination, the alkenes were again used for the synthesis of alkanes. The yield of alkanes (di-tertiary-alkylmethanes VI) was 6-12%, calculated on the tertiary chloride (V) taken for the reaction. The starting alkenes recovered from the reaction contained small amounts of saturated hydrocarbons with the same carbon skeleton, formed as a result of exchange of the chlorine atom in the tertiary chloride for the MgBr group:



EXPERIMENTAL

Homomesitone A was obtained by the reaction of methyl ethyl ketone with calcium carbide in a Soxhlet apparatus. The unreacted methyl ethyl ketone was evaporated and the residue distilled on a column of 80 theoretical plates. We collected and subsequently used a fraction with b. p. 165-167° (750 mm), n_D²⁰ 1.4472, d₄²⁰ 0.8566.

Literature data [6]: b. p. 165-167° (760 mm), n_D²⁰ 1.4476, d₄²⁰ 0.8560.

The problem of the purity of 3-methylheptenone-5 (homomesitone A), i.e., whether 3,4-dimethylhexenone-5 (homomesitone B) was absent from it or not, was solved in the following way: hydrogenation of homomesitone A (b. p. 165-167°) led to 3-methylheptane, which did not contain 3,4-dimethylhexane, as shown by its Raman spectrum.

The material was hydrogenated over nickel on aluminum oxide at 210°; after drying, the catalyzate was distilled over sodium on a column of 35 theoretical plates: b. p. 117-117.5° (748 mm), n_D²⁰ 1.3984, d₄²⁰ 0.7061.

Literature data for 3-methylheptane [9]: b. p. 119.1° (760 mm), n_D²⁰ 1.3988, d₄²⁰ 0.7059.

*It should be noted that with the use of the monohydrobromide of 3,5-dimethylheptadiene-2,4 instead of its monohydrochloride, the yield of the corresponding ethylene hydrocarbons was only 27-40% [6].

Below are presented the most intense lines in the Raman spectrum of the 3-methylheptane obtained (with the intensities measured visually against an arbitrary scale in which the intensity of the line at 1442-1460 cm^{-1} is taken as equal to 10 units).

Data obtained in present work	Literature data [10]
296(2); 315(1/f); 764(3); 822(3.5); 874(3); 892(3.5; b/f); 970(2); 1040(2; b); 1066(1); 1085(1.5); 1144(5/f); 1170(4; b); 1296(5); 1354(2.5); 1442-1460(10; b)	298 (8); 315(5; b); 762(5); 821(8); 874(6); 895(11); 978(5); 1040(7; b); 1064(7); 1083(5); 1147(7); 1167(4; b); 1302(8); 1352(4); 1444 (41); 1464(42)

Note. f = fundamental, b = broad.

Judging by the absence from the spectrum presented of the most intense lines of the 3,4-dimethylhexane spectrum (434, 737 and 749 cm^{-1}) [10], it may be assumed that the starting homomesitone A (3-methylheptenone) did not contain traces of homomesitone B (3,4-dimethylhexenone).

Homomesitone was reacted with methylmagnesium bromide by the procedure described previously [6]. The 3,5-dimethylheptadiene-2,4 (possibly with 3-methyl-5-ethylhexadiene-3,5 impurity) isolated in 60% yield had the following constants:

B. p. 136-142° (750 mm), n_D^{20} 1.4504, d_4^{20} 0.7681.

Literature data [11]; b. p. 136-142° (760 mm), n_D^{20} 1.4495, d_4^{20} 0.7675.

Hydrochlorination of 3,5-dimethylheptadiene-2,4. 3-Chloro-3,5-dimethylheptene-4 (monohydrochloride of 3,5-dimethylheptadiene-2,4) (III) was obtained by passing dry gaseous hydrogen chloride into a snow- and salt-cooled mixture of diene hydrocarbons (62 g, 0.5 mole) until the increase in weight was 19 g. The excess hydrogen chloride was then flushed away with dry air; the monohydrochloride was dried for 5 minutes with calcium chloride and reacted with the organomagnesium compound (if stored or distilled, the hydrochloride lost a noticeable amount of hydrogen chloride).

Synthesis of alkenes (IV). With cooling in ice water and stirring, to an ether solution of alkylmagnesium bromide (1.5 mole of alkyl bromide, 36 g of magnesium and 300 ml of absolute ether) was added dropwise an ether solution of the monohydrochloride (III), obtained from 1 mole of the mixture of dienes. Stirring was continued for 1 hour with cooling and for 3 hours at room temperature; the next day, the reaction mixture was boiled for 4 hours. It was decomposed with dilute acetic acid. The residue after removal of the ether from the washed and dried ether extract was distilled over sodium and then fractionated on a column of 34 theoretical plates. In all the experiments, the low-boiling fractions yielded the starting mixture of dienes with b.p. 136-142° (obtained by elimination of hydrogen chloride from the monohydrochloride).

The yields of alkenes (IV) were 40-50%, calculated on dimethylheptadiene; their constants are presented in Table 1.

Hydrochlorination of alkenes. The alkenes (IV), first saturated with hydrogen chloride, while cooled in ice and salt, were shaken for 3 days with hydrochloric acid, saturated with hydrogen chloride in the cold. The tertiary chlorides (V) obtained (yield of about 90%; not described in the literature) were washed with water, dried with calcium chloride and vacuum distilled. The constants and analysis data are presented in Table 2.

Since the tertiary chlorides partially lost hydrogen chloride on distillation (especially the last of them where $R = \text{iso-C}_3\text{H}_7$), they were usually reacted with the organomagnesium compound without distillation.

Synthesis of ditertiary-alkylmethanes (VI). To an ether solution of alkylmagnesium bromide (24.3 g of magnesium, 1 mole of alkyl bromide and 200 ml of absolute ether) was added 4 g of mercuric chloride and at 12-15°, the tertiary chloride (V) (0.5 mole) was introduced dropwise. The reaction mixture was stirred for a further 2 hours at room temperature and for 4-5 hours with heating; it was decomposed with dilute hydrochloric acid. After the usual treatment of the ether extract and removal of the ether, the residue was freed from organomercury compounds by boiling with sodium for 30 minutes with subsequent

vacuum distillation; two fractions were collected in each case: the low-boiling fraction contained alkene (IV), whose yield was about 60% and the high-boiling one contained alkane (VI), which was shaken for 1 hour with hot (50–60°) concentrated hydrochloric acid (for complete removal of organomercury compounds), washed with water, dried with calcium chloride, distilled over sodium and fractionated on a column of 35 theoretical plates. The alkenes (IV) formed were again used for the synthesis of alkanes (VI).

TABLE 1

Alkenes of Structure $\text{C}_2\text{H}_5-\text{C}=\text{CH}-\text{C}-\text{R}$
 $\begin{array}{c} \text{C}_2\text{H}_5 \\ | \\ \text{CH}_3 \end{array}$ $\begin{array}{c} \text{C}_2\text{H}_5 \\ | \\ \text{CH}_3 \end{array}$

R	Name	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	Literature Data [6]		
					b. p. (pressure in mm)	n_D^{20}	d_4^{20}
C_2H_5	3,5-Dimethyl-5-ethylheptene-3	173–173.5° (750)	1.4412	0.7776	173–173.3 (740)	1.4408	0.7771
C_3H_7	3,5-Dimethyl-5-ethyloctene-3	191–192 (748)	1.4430	0.7805	191.4 (756)	1.4432	0.7800
iso- C_3H_7	3,5,6-Trimethyl-5-ethylheptene-3	194–195 (755)	1.4488	0.7914	194.5–195 (754)	1.4492	0.7913

TABLE 2

Tertiary Chlorides of Structure $\text{R}-\text{C}-\text{CH}_2-\text{C}-\text{Cl}$
 $\begin{array}{c} \text{C}_2\text{H}_5 \\ | \\ \text{CH}_3 \end{array}$ $\begin{array}{c} \text{C}_2\text{H}_5 \\ | \\ \text{CH}_3 \end{array}$

R	Name	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR _D		Found (%)		Calc. (%)	
					found	calc.	C	H	C	H
C_2H_5	5-Chloro-3,5-dimethyl-3-ethylheptane	85–86°(8)	1.4579	0.9129	57.08	57.86	69.16, 69.21	11.96, 11.98	69.26	12.15
C_3H_7	3-Chloro-3,5-dimethyl-5-ethyloctane	74–75 (3)	1.4581	0.9048	61.76	62.48	70.45, 70.64	12.23, 11.97	70.37	12.30
iso- C_3H_7	5-Chloro-2,3,5-trimethyl-3-ethylheptane	78–79 (4)	1.4628	0.9160	61.60	62.48	70.41, 70.52	12.26, 12.22	70.37	12.30

The constants, yields and analysis data of the ditertiary-alkylmethanes (VI) synthesized, which are not described in the literature, are given in Table 3.

The Raman spectra of all the ditertiary-alkylmethanes (VI) we synthesized were examined.* The spectrum of each hydrocarbon contained intense lines in the regions 670–750 and 1200–1250 cm^{-1} , which confirms

* We would like to thank E. G. Treshchova for the optical investigations.

TABLE 3

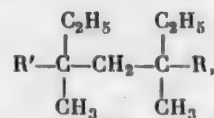
Ditertiary-alkylmethanes of Structure R'-C(CH₃)₂-C(CH₃)₂-R

R	R'	Name	B. p. (pressure in mm)	n _D ²⁰	d ₄ ²⁰	MR _D			Found (%)		Calc. (%)		Yield [in % calc. on the tertiary chloride (%)]
						found	calc. skil's method*	calc. (by Tatev- skii's method)	C	H	C	H	
C ₂ H ₅	C ₂ H ₅	3,5-Dimethyl-3,5-diethylheptane	221.5°(745); 92-92.5 (8)	1.4481	0.8045	61.37	62.23	61.49	84.69, 84.59	15.34, 15.29	84.70	15.30	12
C ₃ H ₇	C ₃ H ₇	4,6-Dimethyl-4,6-diethylnonane	90 (2)	1.4507	0.8069	70.88	71.47	70.78	84.82, 85.01	15.23, 15.18	84.80	15.20	6
C ₃ H ₇	iso-C ₃ H ₇	2,3,5-Trimethyl-3,5-diethyloctane	84.5 (2)	1.4549	0.8155	70.63	71.47	70.57	84.94, 85.00	15.24, 15.29	84.80	15.20	9
iso-C ₃ H ₇	iso-C ₃ H ₇	2,3,5,6-Tetramethyl-3,5-diethylheptane	247-248 (749); 83.5 (2)	1.4600	0.8269	70.34	71.47	70.36	84.81, 84.83	15.38, 15.22	84.80	15.20	10

their structures as alkanes with quaternary carbon atoms [13, 14]; the spectra showed no frequencies in the region 1600-1680 cm⁻¹, indicating the absence of alkenes from the alkanes obtained.

SUMMARY

1. A new general method was developed for the synthesis of the difficultly accessible and previously undescribed ditertiary-alkylmethanes of the structure



where R and R' - are identical or different radicals.

2. The synthesis included the following stages: a) condensation of methyl ethyl ketone to 3-methylheptene-3-one-5; b) synthesis of 3,5-dimethylheptadiene-2,4 (with possible traces of the isomeric diene with the same carbon skeleton, 3-methyl-5-ethylhexadiene-3,5) by the reaction of methylheptenone with methylmagnesium bromide; c) hydrochlorination of dimethylheptadiene; d) reaction of the tertiary allyl chloride formed (3-chloro-3,5-dimethylheptene-4) with alkylmagnesium bromides; e) hydrochlorination of the alkenes (products of this reaction), preparation of tertiary saturated chlorides containing one quaternary carbon atom (3-chloro-3,5-dimethyl-5-ethylalkanes) and f) reaction of these tertiary chlorides with organo-magnesium compounds (in the presence of mercuric chloride).

3. By the method developed, 3,5-dimethyl-3,5-diethylheptane, 4,6-dimethyl-4,6-diethylnonane, 2,3,5-trimethyl-3,5-diethyloctane and 2,3,5,6-tetramethyl-3,5-diethylheptane were synthesized for the first time.

4. Some tertiary monochlorides with one quaternary carbons atom in the chain are described for the first time.

* As the previous columns show, the molecular refractions (MR_D) found differ considerably (by 0.7- 1.1) from the values calculated by the usual scheme (from atomic refractions); therefore, we also present the MR_D values calculated by V. M. Tatevskii's method [12], which allows for the sub-type of chemical bond.

LITERATURE CITED

- [1] R. Ya. Levina, Yu. S. Shabarov, V. K. Daukshas and E. G. Treshchova, *Proc. Acad. Sci. USSR*, **113**, 1286 (1957).*
- [2] R. Ya. Levina, Yu. S. Shabarov and V. K. Daukshas, *J. Gen. Chem.*, **28**, 2046 (1958).*
- [3] A. Abbot, G. Kon, and R. Satchell, *J. Chem. Soc.*, **1928**, 2514.
- [4] J. Colonge, *Bull. Soc. Chim.*, [4], **49**, 441 (1931).
- [5] V. Grignard and Fluchaire, *Ann. Chim.*, [10], **9**, 5 (1916).
- [6] R. Ya. Levina and N. P. Shusherina, *J. Gen. Chem.*, **20**, 868 (1950);* 577 (1952).*
- [7] F. Edgar, G. Calingaert, and R. Marker, *J. Am. Chem. Soc.*, **60**, 2571 (1938).
- [8] A. D. Petrov and E. A. Chernyshev, *Proc. Acad. Sci. USSR*, **86**, 957 (1952).
- [9] J. Smittenberg, H. Hoog, and R. A. Henkes, *J. Am. Chem. Soc.*, **60**, 17 (1938).
- [10] G. S. Landsberg, P. A. Bazhulin and M. M. Sushchinskii, *Basic Parameters of Raman Spectra of Hydrocarbons*, Acad. Sci. USSR Press, **119**, 127 (1956).**
- [11] R. Ya. Levina, N. P. Shusherina, N. I. Volchinskaya and M. Yu. Lur'e, *J. Gen. Chem.*, **23**, 400 (1953).*
- [12] V. M. Tatevskii, *Chemical Structure of Hydrocarbons and Rules of Their Physicochemical Properties*. Moscow State University Press, 287-296 (1953).
- [13] B. I. Stepanov, *J. Phys. Chem.*, **20**, 917 (1946).
- [14] E. G. Treshchova, P. A. Akishin and V. M. Tatevskii, *J. Anal. Chem.*, **3**, 75, (1948).

Received February 19, 1958

*Original Russian pagination. See C.B. Translation.

** In Russian.

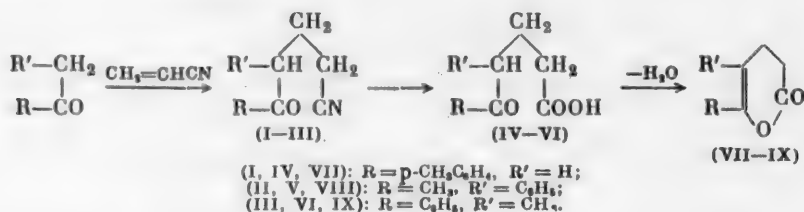
δ-LACTONES

XVI. SYNTHESIS OF ARYL-SUBSTITUTED δ-ENOL LACTONES

N. P. Shusherina, I. S. Trubnikov and R. Ya. Levina

Moscow State University

We previously described the synthesis of 6-phenyl-3,4-dihydro-α-pyrone from monocyanoethylated acetophenone [1]. In the present work a synthesis is described for other aryl-substituted δ-enol lactones from monocyanoethylated methyl p-tolyl ketone, methyl benzyl ketone and propiophenone; the synthesis was accomplished by the following general scheme:



Methyl p-tolyl ketone was monocyanoethylated by the procedure which we developed previously [1] for the cyanoethylation of acetophenone. Methyl benzyl ketone and propiophenone were reacted with acrylonitrile under the normal conditions for the monocyanoethylation of ketones [2, 3].

Hydrolysis of the δ-keto nitriles obtained (I-III) and lactonization of the δ-keto acids formed (IV-VI) lead to the formation of three isomeric aryl-substituted δ-enol lactones: 6-(p-tolyl)-3,4-dihydro-α-pyrone (VII), 6-methyl-5-phenyl-3,4-dihydro-α-pyrone (VIII) and 5-methyl-6-phenyl-3,4-dihydro-α-pyrone (IX).

EXPERIMENTAL

Monocyanoethylation of Ketones*

γ-(p-Tolyl)-butyronitrile (I; monocyanoethylated methyl p-tolyl ketone). 1.5 ml of a 40% methanol solution of potassium hydroxide was added dropwise to 192 g (1.5 mole) of methyl p-tolyl ketone; 15.8 g (0.3 mole) of acrylonitrile was added to the mixture obtained in small portions with vigorous mechanical stirring. The course of the reaction was controlled by the rise in the temperature of the reaction mixture, which was not allowed to exceed 25°; the temperature was kept exactly in the range 20-25° by periodic cooling with water. After the addition of acrylonitrile (complete after 45 minutes), the mixture was left overnight; the excess ketone was then removed by distillation and the residue vacuum distilled. The monocyanoethylated methyl p-tolyl ketone obtained (17.7 g; 31% yield; not described in the literature) had the following constants: b. p. 200-207° (7 mm), m. p. 59.5-60.5° (from methyl alcohol).

Found %: C 77.19, 77.19; H 7.03, 7.05. C₁₂H₁₃ON. Calculated %: C 76.97; H 7.00.

* Before use in reactions, the starting ketones (methyl p-tolyl ketone, propiophenone and methyl benzyl ketone) were shaken with 2N sodium carbonate solution, salted out and distilled.

γ -Phenyl- γ -acetylbutyronitrile (II; monocynoethylated methyl benzyl ketone). With cooling with ice and stirring, 13.0 ml 0.2 mole) of acrylonitrile was added dropwise to a mixture of 135 g (1 mole) of methyl benzyl ketone and 1 ml of a 40% methanol solution of potassium hydroxide at such a rate that the temperature of the reaction mixture did not exceed 10-15°.

The mixture was then stirred for 5-6 hours, the excess ketone removed by distillation and the residue vacuum distilled. The γ -phenyl- γ -acetylbutyronitrile obtained (30 g; yield 80%; not described in the literature) was redistilled in vacuum:

B. p. 149-150° (6 mm), 170-171° (12 mm), n_D^{20} 1.5182, d_4^{20} 1.0530, MR_D 53.93; calc. 53.84.

Found %: C 77.05, 77.07; H 7.17, 7.12. $C_{12}H_{13}ON$. Calculated %: C 76.97; H 7.00.

γ -Benzoylvaleronitrile (III; monocynoethylated propiophenone) was obtained from 67 g (0.5 mole) of propiophenone and 6.5 ml (0.1 mole) of acrylonitrile by the procedure described above for methyl benzyl ketone. The yield was 65% (12.5 g).

B. p. 180-183° (13 mm), 175-178° (10 mm), n_D^{20} 1.5260.

Literature data: b. p. 121-123° (17 mm), n_D^{20} 1.5261 [3]; b. p. 135° (0.4 mm), n_D^{20} 1.5265 [4].

Hydrolysis of δ -Keto Nitriles

γ -(p-Tolyl)-butyric acid (IV). 16 g of γ -(p-tolyl)-butyronitrile, 30 ml of water and 60 ml of concentrated hydrochloric acid were boiled together for 5 hours. The cooled reaction mixture deposited crystals of γ -(p-tolyl)-butyric acid (yield quantitative); the m. p. was 148-149° (from benzene). Literature data; m. p. 148-149° [5], 150.5-152.5° [6].

γ -Phenyl- γ -acetylbutyric acid (V). 28 g of γ -phenyl- γ -acetylbutyronitrile, 60 ml of water and 120 ml of concentrated hydrochloric acid were boiled together for 4 hours. The reaction mixture was then diluted with an equal volume of water and extracted with ether. When the ether solution had been dried with baked magnesium sulfate and the ether removed, the residue was vacuum distilled. The γ -phenyl- γ -acetylbutyric acid (not described in the literature), which was obtained in quantitative yield, had the following constants:

b. p. 194-195° (7 mm), n_D^{20} 1.5240, d_4^{20} 1.1350, MR_D 55.60; calc. 55.56.

Found %: C 69.92, 69.61; H 6.94, 7.00. $C_{12}H_{14}O_3$. Calculated %: C 69.88; H 6.98.

When kept for 2 days in a refrigerator, the substance crystallized; the m. p. was 43-44° (from a mixture of petroleum ether and benzene).

γ -Benzoylvaleric acid (VI) was obtained in 95% yield from γ -benzoylvaleronitrile (38 g) (by the procedure described for γ -phenyl- γ -acetylbutyric acid) and had the following constants (it is not described in the literature):

b. p. 198-202° (10 mm), n_D^{20} 1.5332, d_4^{20} 1.1370, MR_D 56.32; calc. 55.56; EM_D 0.76.

Found %: C 69.98, 69.87; H 6.98, 6.95. $C_{12}H_{14}O_3$. Calculated %: C 69.88; H 6.98.

When kept in a refrigerator for several days, the substance crystallized; the m. p. was 52-53° (from petroleum ether).

Preparation of δ -Enol Lactones

6-(p-Tolyl)-3,4-dihydro- α -pyrone (VII). A mixture of 18 g of γ -(p-tolyl)-butyric acid and 100 ml of acetic anhydride was boiled for 4 hours. After removal of the acetic acid and the excess acetic anhydride, the residue was vacuum distilled. The 6-(p-tolyl)-3,4-dihydro- α -pyrone (12 g, 73% yield) obtained had the following constants:

b. p. 183-185° (9 mm), m. p. 64.5-65° (from alcohol).

Found %: C 75.99, 75.97; H 6.62, 6.61. $C_{12}H_{12}O_2$. Calculated %: C 76.58; H 6.43.

6-Methyl-5-phenyl-3,4-dihydro- α -pyrone (VIII) was obtained from γ -phenyl- γ -acetylbutyric acid by the procedure described above (65% yield);

b. p. 163-164° (7 mm), n_D^{20} 1.5582, d_4^{20} 1.1275, MR_D 53.86; calc. 53.00; EM_D 0.86.

Found %: C 76.78, 76.88; H 6.50, 6.47. $C_{12}H_{12}O_2$. Calculated %: C 76.58; H 6.43.

5-Methyl-6-phenyl-3,4-dihydro- α -pyrone (IX) was obtained from 14.3 g of γ -benzoylvaleric acid by the procedure described above for 6-(p-tolyl)-3,4-dihydro- α -pyrone and had the following constants; b. p. 187° (18 mm), 160° (5 mm); m. p. 58-58.5°. The yield was 66% (7.1 g).

Found %: C 76.84, 76.67; H. 6.53, 6.57. $C_{12}H_{12}O_2$. Calculated %: C 76.58; H 6.43.

SUMMARY

1. The monocyanoethylation of the methyl-p-tolyl ketone and methyl benzyl ketone was achieved for the first time.

2. The isomeric aryl-substituted δ -enol lactones 6-(p-tolyl)-3,4-dihydro- α -pyrone, 6-methyl-5-phenyl-3,4-dihydro- α -pyrone and 5-methyl-6-phenyl-3,4-dihydro- α -pyrone (not described in the literature) were synthesized.

LITERATURE CITED

- [1] M. Yu. Lur'e, I. S. Trubnikov, N. P. Shusherina and R. Ya. Levina, J. Gen. Chem. 28, 1351 (1958).*
- [2] M. Baumgarten and R. Eifert, J. Am. Chem. Soc., 75, 3013 (1953).
- [3] A. P. Terent'ev, A. N. Kost, Yu. V. Saltykova and V. V. Ershov, J. Gen. Chem., 26, 2925 (1956).*
- [4] R. Fuson and T. Miller, J. Org. Ch., 17, 886 (1952).
- [5] F. Garter, J. Simonsen and H. Williams, J. Chem. Soc., 1940, 451.
- [6] J. Vila and R. Crespo, Anales real. soc. espan. fis. y quim., 48, 273 (1952); Ch. A. 47, 3802 (1953).

Received March 4, 1958

*Original Russian pagination. See C.B. Translation.

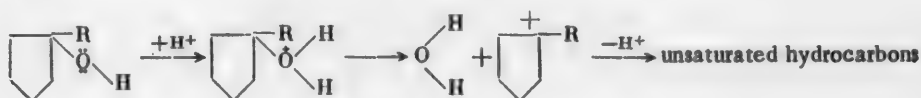
DEHYDRATION OF 1-ALKYLCYCLOPENTANOLS

A. F. Platé and A. A. Mel'nikov

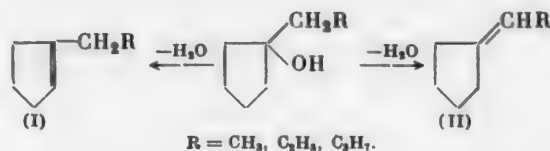
Moscow State University

The dehydration of tertiary alkylcycloalkanols containing a hydroxyl group in the ring, which gives unsaturated cyclic hydrocarbons, has hardly been studied. We ran into this problem since for subsequent syntheses we required 1-ethylcyclopentene-1, 1-n-propylcyclopentene-1 and 1-n-butylcyclopentene-1 with a high degree of purity and without isomers containing the double bond in another position.

The mechanism of alcohol dehydration in an acid medium apparently consists of, firstly, the addition of a proton to the electron pair of the oxygen atom and then rupture of the C-O bond with the formation of a molecule of water and a carbonium ion [1], which is stabilized by the ejection of one of the neighboring hydrogen atoms as a proton and as a result of this an unsaturated hydrocarbon is formed [2].



The last stage proceeds according to the Zaitsev rule: the hydrogen atom is eliminated from the carbon atom which bears the least hydrogens. In the general case, the formation of three different olefins is possible by the dehydration of tertiary alcohols. In the case of 1-alkylcyclopentanol-1, there is the possibility of the formation of two isomers, differing in the position of the double bond, alkylcyclopentenes (I) and alkylidenecyclopentanes (II), where the formation of the two isomers is equally probable according to the Zaitsev rule.



However, from an examination of papers in which the dehydration of alkylcyclopentanol-1 is mentioned, it is usually assumed that only one isomer of type (I) will be formed. It is true that we should mention that in most papers the position of the double bond in the hydrocarbons synthesized was not of great importance since the latter were used predominantly for synthesis of the corresponding homologs of cyclopentane and the hydrogenation of isomers (I) and (II) forms the same saturated hydrocarbon. A study was made of the nature of the dehydration products formed in the presence of iodine, using the example of certain alkylcyclohexanols [3]. It was shown that 1-methylcyclohexanol-1 formed only 1-methylcyclohexene-1; the dehydration of 1-ethylcyclohexanol-1 formed 1-ethylcyclohexene-1 with only 1% ethylidenecyclohexane; together with 1-isopropylcyclohexene-1, the dehydration of 1-isopropylcyclohexanol-1 formed 5% of isopropylidenecyclohexane.

The nature of the hydrocarbons formed in the dehydration of 1-alkylcyclopentanol-1 had not been studied in such detail. In connection with this we should note the investigation of Brown, Brewster and Shechter [4], who analyzed available material and came to the conclusion that the reactions proceeded in such a way that they favored the formation or retention of a semicyclic double bond in the case of a five-membered ring

and so as to avoid the formation or retention of a semicyclic double bond in the case of a six-membered ring. The authors assumed that the introduction of a semicyclic double bond stabilizes a five-membered ring while the introduction of a double bond into a five-membered ring increases its strain.

The dehydration of alcohols is normally accomplished in the presence of acid catalysts, which lead to the isomerization of compounds of type (II) into compounds of type (I) in a series of cases. Such an isomerization with transfer of the double bond into the ring in the presence of sulfuric acid [5] and even in the presence of benzoic acid [6] occurs in the case of unsaturated hydrocarbons with a six-membered ring. Isomerization with transfer of the multiple bond from the semicyclic position into the ring occurs even in the case when the double bond in the original compound is conjugated with a phenyl nucleus. Thus, for example, benzylidenecyclohexane is converted into 1-benzylcyclohexane-1 by the action of potassium bisulfate [7]. Thus, the statement of Brown, Brewster and Shechter [4] as regards six-membered rings is confirmed by a large amount of experimental material; however, their statement on the greater stability of compounds with a semicyclic double bond does not always agree with available, though scant, data and requires further experimental testing. Thus, in the presence of sulfuric acid, isopropylidenecyclopentane is isomerized into 1-isopropylcyclopentene-1 [8]. B. A. Kazanskii and G. T. Tatevosyan [9] showed that a similar isomerization occurred, as well, in the presence of crystalline oxalic acid, since in the dehydration of dimethylcyclopentylcarbinol they obtained largely 1-isopropylcyclopentene-1. The dehydration of 1-isopropylcyclopentanol-1 with zinc chloride yielded only 1-isopropylcyclopentene-1.

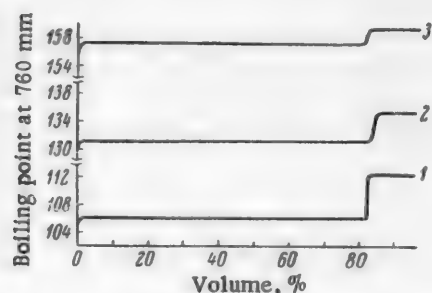


Fig. 1. Distillation curves of 1-alkylcyclopentenes-1 and alkylidenecyclopentanes.
1) C_7H_{12} , 2) C_8H_{14} , 3) C_9H_{16} .

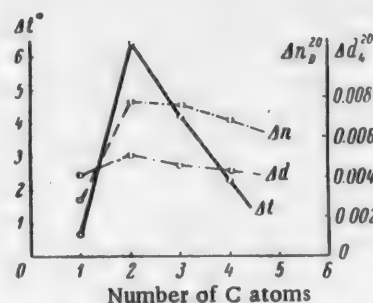


Fig. 2. Dependence of Δt , Δn and Δd for alkylidenecyclopentanes and 1-alkylcyclopentenes-1 on the number of carbon atoms in the side chain.

propylcyclopentene-1 [10]. Isomerization with transfer of the semicyclic double bond into the ring in the presence of an aluminochromium catalyst was studied in detail by R. Ya. Levina, N. N. Mezentsova and P. A. Akishin for both cyclohexane and cyclopentane hydrocarbons [11]. Turner and Garner [12] recently showed that when heated with a solution of *p*-toluenesulfonic acid in acetic acid, methylenecyclopentane was completely isomerized into 1-methylcyclopentene-1. However, this case cannot be considered characteristic, since the absence of a methyl group from methylenecyclopentane and its presence in 1-methylcyclopentene-1 may have a considerable effect on the stability of the two isomers, though we cannot but note that all the facts presented above contradict the statement [4] on the stability of compounds with a semicyclic double bond at a five-membered ring.

It seemed to us that valuable data could be obtained by studying the dehydration products of alkylcyclopentanol. We carried out the dehydrations with a saturated solution of oxalic acid [13]. The mixture of unsaturated hydrocarbons obtained in 79-83% yield was fractionated on a column with an efficiency of 80 theoretical plates. The distillation curves are presented in Fig. 1. In each of the cases studied, it was found that the elimination of water did not proceed in one, but in both possible directions, with the formation of hydrocarbons of types (I) and (II) in a rate of approximately 7 : 1. The constants of the alkylidenecyclopentanes were higher than those of the 1-alkylcyclopentenes-1: the b. p. was higher by 2.3-6.4°, n_D^{20} by 0.0068-0.0078 and d_4^{20} by 0.0043-0.0051. As Fig. 2 shows, the greatest difference in boiling point is observed in the case of the hydrocarbons C_7H_{12} ; with an increase in the molecular weight, this difference decreases sharply. Apparently, the boiling points of the pairs of homologs following $C_{10}H_{18}$ and of similar structure (which have not

been synthesized as yet) will be so close that it will be impossible to separate the hydrocarbons by distillation; Δn and Δd differ less sharply. The Raman spectra of the hydrocarbons obtained, which we studied, [14] confirmed their structures. Thus, it was found that the frequency in the region of double-bond valence oscillations of 1-alkylcyclopentenes-1 equaled $1650\text{--}1652\text{ cm}^{-1}$ and of alkylidenecyclopentanes, $1678\text{--}1682\text{ cm}^{-1}$. Besides the constants listed above, the crystallization temperatures of all the hydrocarbons (with the exception of *n*-butylidenecyclopentane, which vitrified) were determined; the degree of purity, which was determined for 1-ethylcyclopentene-1, 1-*n*-propylcyclopentene-1 and 1-*n*-butylcyclopentene-1, was found to be 98.6, 98.9 and 97.5 mole % [15].* The constants of the alcohols obtained are presented in Table 1 and those of the hydrocarbons in Table 2.

In the synthesis of 1-*n*-propylcyclopentanol by the Grignard reaction, as a result of reduction of cyclopentanone, a certain amount of cyclopentanol was formed, as was shown previously in the work of Chavanne and Becker [16]. There are reports [17], in the literature on the reducing capacity of Grignard reagents and in a series of papers, it has been the subject of a special investigation [18]. The reducing capacity increases in the series ethylmagnesium halide to *n*-amylmagnesium halide and most sharply in going from ethylmagnesium halide to *n*-propylmagnesium halide.

TABLE 1

Properties of 1-alkylcyclopentanol

Alcohol	Boiling point (pressure in mm)	Crystallization point	n_D^{20}	d_4^{20}	M_R	
					found	calc.
1-Ethylcyclopentanol-1 ^a	151.5—152° (750) 58—58.5 (14) 48.5 (8)	—1.3	1.4540	0.9184	33.67	33.85
1- <i>n</i> -Propylcyclopentanol-1 ^b	64—65.5 (10)	—43	1.4542	0.9045	38.40	38.47
1- <i>n</i> -Butylcyclopentanol-1 ^c	91 (15) 87—88 (13) 78—79 (8)	—	1.4572	0.9000	43.06	43.08

Notes. a) B. p. 74.5° (20 mm) [22]; $150\text{--}152^\circ$ (750 mm) d_4^{20} 0.9243 [23]; m. p. -8° [24]; d_4^{20} 0.9218, n_D^{20} 1.4532 [25]; $n_D^{18.9}$ 1.4545 [16].

b) B. p. 71° (8.5 mm), m. p. -37.5° [22]; b. p. $175.2\text{--}175.7^\circ$ (760 mm); n_D^{20} 1.4540, d_4^{20} 0.9044 [16].

c) B. p. 99° (20 mm), 86° (9 mm) [22]; $195.4\text{--}195.9^\circ$ (760 mm), $n_D^{19.15}$ 1.4562, $d_4^{19.6}$ 0.8989 [16].

Together with the dehydration of pure 1-*n*-propylcyclopentanol-1, we also dehydrated fractions of this alcohol containing a certain amount of cyclopentanol. When a mixture obtained by the dehydration of such fractions was distilled on a column, besides 1-*n*-propylcyclopentene-1 and propylidenecyclopentane, we also isolated a head fraction (Fig. 3); in boiling point and refractive index, this fraction corresponded to the fraction obtained by Chavanne and Becker [16] in the synthesis of 1-*n*-propylcyclopentene-1, which they considered as an isomeric hydrocarbon differing from propylidenecyclopentane, but whose nature they did not establish. As we showed, this fraction is an azeotropic mixture of 1-*n*-propylcyclopentene-1 and cyclopentanol

*The crystallization temperatures and the degrees of purity were determined in Chemical Thermodynamics Laboratory of Moscow State University by A. G. Anikin and G. M. Dugacheva, whom the authors take this opportunity to thank.

with the composition 73.7 : 26.3 weight %. The possibility of the formation of azeotropic mixtures of unsaturated hydrocarbons and alcohols in the distillation of products obtained by the Grignard reaction was reported by one of us previously [19]. It is interesting to note that the crystallization point of this azeotropic mixture (-98.4°) is somewhat higher than that of pure 1-n-propylcyclopentene-1 (-98.8°). We also studied the behavior of ethylidenecyclopentane and 1-ethylcyclopentene-1 under the dehydration conditions. It was found that when boiled for 4 hours with a saturated aqueous solution of oxalic acid, 1-ethylcyclopentene-1 did not change and ethylidenecyclopentane (judging by its refractive index) was 11.5% converted into 1-ethylcyclopentene-1, i.e., there was transfer of the double bond from the semicyclic position into the ring.

From the data obtained it follows that there is a difference between the behavior of alkylcyclopentanol and the corresponding six-membered analogs under dehydration conditions [3]; in the case of the former, a noticeable amount of hydrocarbons with a semicyclic double bond is formed. To a certain extent, these results confirm the ideas which Brown, Brewster and Shechter [4] put forward on the greater stability of five-

TABLE 2

Properties of 1-Alkylcyclopentenes-1 and Alkylidenecyclopentanes

Hydrocarbons	B. p. at 760 mm	Crystallization point		Degree of purity	n_D^{20}	d_4^{20}	MR_b	
		initial	calculated on no impurities in the hydrocarbon				found	calculated
1-n-Alkylcyclopentenes-1								
1-Ethylcyclopentenes-1 ^a	106.0°	-118.55	-118.3	98.6	1.4418	0.7979	31.88	31.85
1-n-Propylcyclopentene-1 ^b	131.1	-99.0	-98.7	98.9	1.4448	0.8004	36.63	36.48
1-n-Butylcyclopentene-1 ^c	157.1	-88.35	-87.9	97.5	1.4482	0.8062	41.26	41.09
Alkylidenecyclopentanes								
Ethylidenecyclopentane ^d	112.4	-129.5	—	—	1.4496	0.8030	32.15	31.85
n-Propylidenecyclopentane ^e	135.3	-116.5	—	—	1.4524	0.8050	36.96	36.48
n-Butylidenecyclopentane ^e	159.4	Vitrifies	—	—	1.4550	0.8105	41.58	41.09

Notes. a) Cryst. p. -118.4° , b. p. 106.3° (760 mm), n_D^{20} 1.4410, d_4^{20} 0.7982 [26].

b) M. p. -100.3° [27], b. p. $131.5-132.5^{\circ}$, n_D^{20} 1.4450, d_4^{20} 0.8015 [16].

c) M. p. -95.75° , b. p. $157.5-158^{\circ}$ (760 mm) [16], 154.5° (750 mm), n_D^{20} 1.4489, d_4^{20} 0.8065 [28].

d) B. p. 112.6° (760 mm), n_D^{20} 1.4490, d_4^{20} 0.8030 [29].

e) Obtained for the first time.

membered compounds with a semicyclic double bond in comparison with the corresponding six-membered ones. However, for five-membered cyclic unsaturated hydrocarbons, as for six-membered ones, the most stable form is the one with the double bond in the ring. It should be assumed that data published up to the present time on 1-alkylcyclopentenes-1, in a series of cases refers to preparations which contain a greater or lesser amount of impurities corresponding to their isomeric alkylidenecyclopentanes.

EXPERIMENTAL

All the tertiary alcohols were obtained by the Grignard reaction from appropriate alkylmagnesium bromides and cyclopentanone. Individual experiments were performed with 5-6 moles of each of the starting materials. The alcohols obtained were fractionated twice in vacuum. The small head and tail fractions obtained in the synthesis of 1-ethylcyclopentanol-1 and 1-n-butylcyclopentanol-1 were discarded and those obtained in the synthesis of 1-n-propylcyclopentanol-1 were dehydrated and treated separately.

For the dehydration, the alcohol (1 volume) and a saturated aqueous solution of oxalic acid (2 volumes) were placed in a Favorskii flask. As the hydrocarbon steam distilled, water was introduced into the flask so that the concentration of the oxalic acid solution was kept approximately constant. The dehydration product was separated from the aqueous layer, washed with sodium carbonate solution, dried with baked potassium carbonate and distilled, first from a flask with a still head and then on a column with a metal packing and an efficiency of 80 theoretical plates. The distillation curves are shown in Fig. 1.

1-Ethylcyclopentanol-1. A total of 2052 g of alcohol was obtained. The yield was 68% (up to 71% in individual experiments) of theoretical. The properties of this and the other tertiary alcohols are presented in Table 1.

After dehydration and distillation of the reaction product on a column, 1-ethylcyclopentanol-1 yielded 83.6% of unsaturated hydrocarbons, of which 1-ethylcyclopentene-1 represented 1235 g or 83.4% of the total amount of unsaturateds, and ethylenecyclopentane, 190 g or 13.3% of the total amount of unsaturateds. Intermediate fractions represented 5 g (0.3%); the residues in the flask (apparently polymerization products formed as a result of prolonged heating) weighed 80.8 g (5.3%); the loss as were 11.2 g (0.7%). The properties of the unsaturated hydrocarbons are presented in Table 2.

Heating of 1-ethylcyclopentene-1 and ethylenecyclopentane with oxalic acid. The unsaturated hydrocarbon (1 volume) was boiled under reflux for 4 hours with a saturated solution of oxalic acid (2 volumes); the hydrocarbon was then steam distilled and worked up as usual. The refractive index of 1-ethylcyclopentene-1 (6.5 g) was unchanged; the refractive index of the ethylenecyclopentane (20 g) changed from n_D^{20} 1.4496 to n_D^{20} 1.4487, i.e., apparently ethylenecyclopentane was 11.5% isomerized to 1-ethylcyclopentene-1.

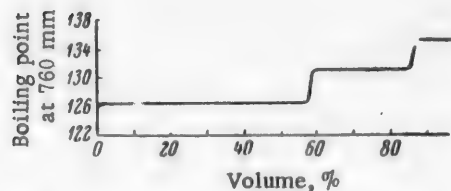


Fig. 3. Distillation curve of the mixture of hydrocarbons obtained by the dehydration of the head and tail fractions of 1-n-propylcyclopentanol-1.

1-n-Propylcyclopentanol-1. After two fractionations in vacuum the following fractions were obtained:

- 1st b. p. up to 64° (10 mm), n_D^{20} 1.4535, 313.4 g;
- 2nd b. p. 64.0-65.5° (10 mm), n_D^{20} 1.4542, 540.9 g (35.1%);
- 3rd b. p. 65.5-70° (10 mm), n_D^{20} 1.4564, 114.7 g.

The first fraction was 1-n-propylcyclopentanol-1 with a trace of cyclopentanol; the third fraction was 1-n-propylcyclopentanol-1, apparently with condensation products of cyclopentanone; the second fraction was pure 1-n-propylcyclopentanol-1. The total yield of alcohol was 60% on the cyclopentanone taken for the reaction.

Found %: C 74.54, 74.30; H 12.30, 12.35. $C_8H_{16}O$.
Calculated %: C 74.94; H 12.58.

In the dehydration of 1-n-propylcyclopentanol-1 we obtained 82% of unsaturated hydrocarbons, of which 1-n-propylcyclopentene-1 represented 306.2 g or 86.9% of the total amount of unsaturateds.

Found %: C 87.24, 87.12; H 12.68, 12.74. C_8H_{14} . Calculated %: C 87.10; H 12.90.

We obtained 33.1 of propylenecyclopentane or 11.1% of the total amount of unsaturateds. The hydrocarbon was obtained for the first time.

Found %: C 87.32, 86.84; H 12.60, 12.50. C_8H_{14} . Calculated %: C 87.10; H 12.90.

The intermediate fraction represented 7.0 g (2%), the residue, 12.8 g (3.5%) and the distillation losses, 2.8 g (0.7%).

The first fraction, containing cyclopentanol, and the third fraction obtained in the distillation of 1-n-propylcyclopentanol-1 (see above) were dehydrated separately. Together with 1-propylcyclopentane-1 and propylidenecyclopentane, distillation of the dehydration products on a column (Fig. 3) yielded a head fraction with the following constants: cryst. p. -98.4° , b. p. 125.6° (760 mm), n_D^{20} 1.4460, d_4^{20} 0.8363; it weighed 189 g. As a result of repeated washing with water, 161.5 g of this fraction yielded 120.0 g of hydrocarbon, which did not differ in constants and analysis from 1-propylcyclopentene-1. After saturation with sodium chloride and extraction with ether, the aqueous solution yielded 40.3 g of cyclopentanol with the following properties:

b.p. 54.7° (16 mm), n_D^{20} 1.4530, d_4^{20} 0.9459, M_R 24.61; calc. 24.61; phenylurethan: m.p. $137.5-138.5^{\circ}$ (from a mixture of acetone and water 1:1). According to literature data [20]: b. p. $139-141^{\circ}$, n_D^{20} 1.4531, d_4^{20} 0.9489; phenylurethan [21]: m. p. $137-138^{\circ}$.

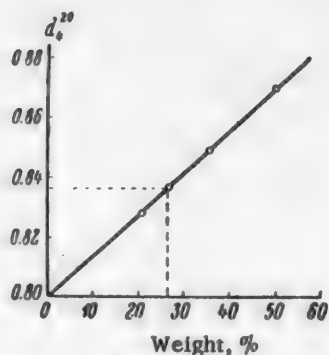


Fig. 4. Graph of changes in specific gravity of mixtures of 1-propylcyclopentene-1 with cyclopentanol.

TABLE 3

Specific Gravities of Mixtures of 1-Propylcyclopentene-1 with cyclopentanol

Alcohol content (in weight %)	d_4^{20}
20.62	0.8285
26.60	0.8366
35.50	0.8487
49.94	0.8691
100.00	0.9459

Thus, the fraction which Chavanne and Becker mentioned [16] was not an individual hydrocarbon as the authors had considered, but an azeotropic mixture of 1-n-propylcyclopentene-1 and cyclopentanol. Treatment of the first and third fractions obtained in the synthesis of 1-propylcyclopentanol-1 yielded a further 224.5 g of 1-n-propylcyclopentene-1 and 28.7 g of propylidenecyclopentane.

For determination of the composition of the azeotropic mixture, artificial mixtures of 1-propylcyclopentene-1 and cyclopentanol were prepared and their specific gravities determined (Table 3). The composition of the azeotropic mixture was determined from the curve of the change in specific gravity with composition (Fig. 4): this was 73.7 weight % of 1-propylcyclopentene-1 and 26.3 weight % of cyclopentanol.

1-n-Butylcyclopentanol-1 (1614 g) was obtained in 57% yield (up to 62% in individual experiments).

The dehydration of 845 g of alcohol gave 79.7% of unsaturated hydrocarbons, of which 1-n-butylcyclopentene-1 formed 508 g or 86.3% of the total amount of unsaturated and n-butylidenecyclopentane, 73.5 g or 12.5%; the latter hydrocarbon was obtained for the first time.

Found %: C 87.47, 87.20; H 12.69, 12.63. C_9H_{18} .
Calculated %: C 87.04; H 12.96.

The intermediate fraction represented 6.8 g (1.2%), the residue, 17.6 g (2.9%) and the distillation losses, 3.1 g (0.5%).

SUMMARY

1. A study was made of the dehydration of 1-ethyl-, 1-n-propyl- and 1-n-butylcyclopentanol-1 in the presence of a saturated solution of oxalic acid.
2. It was shown that under the conditions studied there occurred the formation of unsaturated hydrocarbons both with a double bond in the ring and with a semicyclic double bond; 1-alkylcyclopenten-1 and alkylidenecyclopentanes were obtained in a ratio of approximately 7:1.
3. It was shown that when boiled for 4 hours with aqueous oxalic acid, 1-ethylcyclopentene-1 was unchanged, but ethylidenecyclopentane was 11.5% isomerized into 1-ethylcyclopentene-1.
4. The properties of two previously unknown hydrocarbons, propylidenecyclopentane and butylidenecyclopentane, are presented.

5. It was shown that in the synthesis of 1-n-propylcyclopentanol-1 by the Grignard reaction, due to reduction of cyclopentanone, a certain amount of cyclopentanol is formed and it is difficult to remove this from the alcohol obtained; in the dehydration of this alcohol with such an impurity and subsequent distillation of the reaction products, the 1-n-propylcyclopentene-1 obtained forms an azeotropic mixture with cyclopentanol with the composition 73.7:26.3 (weight %), which was previously accepted as an individual hydrocarbon.

LITERATURE CITED

- [1] O. A. Reutov. Theoretical Problems in Organic Chemistry, Moscow University Press, 369 (1956).*
- [2] F. C. Whitmore, J. Am. Chem. Soc., 54, 3274 (1932).
- [3] W. A. Mosher, J. Am. Chem. Soc., 62, 552 (1940).
- [4] H. C. Brown, J. H. Brewster, and H. Shechter, J. Am. Chem. Soc., 76, 467 (1954).
- [5] O. Wallach, Lieb. Ann., 239, 15 (1887); 360, 29 (1908); 359, 287 (1908); Ber., 39, 2504 (1906).
- [6] A. E. Favorskii and I. Borgman, J. Russ. Chem. Soc., 39, 1225 (1908).
- [7] K. Auwers and W. Treppmann, Ber., 48, 1207 (1915).
- [8] O. Wallach, and K. Fleisher, Lieb. Ann., 353, 308 (1907).
- [9] B. A. Kazanskii and G. T. Tatevosyan, J. Gen. Chem., 9, 2248 (1939).
- [10] H. Meerwein, Lieb. Ann., 405, 153 (1914).
- [11] R. Ya. Levina, N. N. Mezentsova and P. A. Akishin, J. Gen. Chem., 23, 562 (1953);** Bull. Moscow State University, No. 2, 87 (1951).
- [12] R. B. Turner and R. H. Garner, J. Am. Chem. Soc. 79, 253 (1957).
- [13] N. D. Zelinskii and I. A. Tselikov, J. Russ. Chem. Soc., 33, 655 (1901).
- [14] V. T. Aleksanyan, Kh. E. Sterin, A. A. Mel'nikov and A. F. Platé, Bull. Acad. Sci. USSR, Phys. Ser., 22, 1073 (1958).
- [15] A. G. Anikin, G. M. Dugacheva, A. A. Mel'nikov and A. F. Platé, Bull. Moscow State University, No. 1, 227 (1958).
- [16] G. Chavanne and P. Becker, Bull. Soc. Chim. Belg., 36, 591 (1927).
- [17] G. Chiurdoglu, Bull. Soc. Chim. Belg., 42, 347 (1933); H. Suida and A. Gemassmer, Ber., 72, 1168 (1939).
- [18] F. C. Whitmore, et al., J. Am. Chem. Soc., 63, 643 (1943).
- [19] A. F. Platé and G. A. Tarasova, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1941, 201; A. F. Platé and E. A. Mil'vitskaya, Sci. Rep. Moscow State University, No. 132, 248 (1950).
- [20] B. A. Kazanskii, E. M. Terent'eva and T. F. Bulanova, Syntheses of Organic Compounds, Coll. I, Acad. Sci. USSR Press, 161 (1950).*
- [21] A. Stoll, A. Lindenmann, and E. Jucker, Helv. Chim. Acta, 36, 268 (1953).
- [22] C. R. Mc Lellan and W. R. Edwards, J. Am. Chem. Soc., 66, 409, (1944).
- [23] N. D. Zelinskii and I. Pappe, J. Russ. Chem. Soc., 37, 625 (1905).
- [24] W. Hüchel, K. Kumetst and H. Severin, Lieb. Ann., 518, 184 (1935).
- [25] R. Ya. Levina and N. N. Mezentsova, Bull. Moscow State University, No. 1, 205 (1956).
- [26] F. D. Rossini, et al., Selected values of physical and thermodynamic properties of hydrocarbons and related compounds, 64 (1953). *

* In Russian.

** Original Russian pagination. See C.B. Translation.

[27] J. Timmermans, *Bull. Soc. Chim. Belg.*, 61, 393 (1952); *Ch. A.*, 48, 540 (1954).

[28] P. A. Akishin, V. M. Tatevskii, N. G. Rombidi, N. N. Mezentsova and R. Ya. Levina, *J. Phys. Chem.* 30, 660 (1956).

[29] J. R. Van Der Bij, and E. C. Kooyman, *Rec. trav. chim.*, 71, 837 (1952).

Received March 24, 1958

CATALYTIC REACTIONS IN THE PRESENCE OF ALUMINUM METAL

IV. ALKYLATION OF BROMOBENZENE WITH ETHYL BROMIDE, n-PROPYL BROMIDE AND n-BUTYL BROMIDE. ALKYLATION OF IODOBENZENE WITH n-BUTYL BROMIDE

M. B. Turova-Polyak and N. P. Dobrosel'skaya

Moscow State University

We recently established the possibility of alkylating chlorobenzene with ethyl bromide, propyl bromide and butyl bromide in the presence of aluminum metal [1]. As a result of the investigations described in the present article, it was found that bromobenzene was also alkylated readily in the presence of aluminum metal by the alkyl bromides listed above. So as to study the kinetics of liquid-phase alkylation (in the presence of aluminum halides) in more detail, we determined the effect of the following factors on the yield of alkylation products: the nature of the alkylating agent, the ratio of the reagents, the reaction temperature, the duration of heating of the reaction mixture and activation of the aluminum. The work established that there was the same dependence of alkylbromobenzene yield on the nature of the alkyl bromide introduced into the reaction and on the composition of the reaction mixture, as in the case of chlorobenzene alkylation [1]. The yield of alkylbromobenzene increased with an increase in the molecular weight of the alkyl bromide. The best yield of ethylbromobenzene (52%; a mixture of para- and ortho-isomers) was obtained at a molar ratio of benzene : ethyl bromide of 3 : 1 and the best yields of p-isopropylbromobenzene (68-75%) and p-isobutylbromobenzene (72-80%) at a reagent ratio of 5 : 1. Propyl- and butylbromobenzenes of normal structure were absent from the alkylation products. We explain the lower yield of ethylbromobenzene by the fact that under the conditions of our experiments aluminum metal may react with ethyl bromide and form a mixture of two organoaluminum bromides [2-4], due to which the yield of ethylbromobenzene may be reduced.



where R is alkyl and X, halogen. The organoaluminum bromides formed are good catalysts for the further reaction of alkyl halides with aluminum metal [5]. Alkylaluminum halides are formed especially readily in the reaction of aluminum metal with ethyl iodide or bromide. With an increase in the molecular weight of the radicals of the alkyl halides, the reactivity of the latter decreases [6, 7]. Bromobenzene does not react with aluminum metal. However, in the presence of this catalyst, it undergoes partial disproportionation with the formation of benzene and p-dibromobenzene [8, 9]. Then in the work it was shown that heating the reaction mixture above 80° and longer than 30-40 minutes did not produce an increase in the yield of monoalkylbromobenzene, but promoted the formation of polyalkylbromobenzenes and the disproportionation of bromobenzene. The use of activated aluminum raised the yield of alkylbromobenzenes by 7-8%.

An attempt to introduce an alkyl group into the molecule of iodobenzene under our experimental conditions did not lead to positive results. This is apparently explained by the fact that both the alkyl halide and iodobenzene are capable of reacting with aluminum metal by the scheme presented above [5]. In addition, the disproportionation of iodobenzene to benzene and diiodobenzene proceeds more vigorously than in the case of bromobenzene [8]. The reaction of iodobenzene with butyl bromide gave an insignificant amount of butylbromobenzene. Consequently, it was not iodobenzene that was alkylated, but benzene formed as a result of disproportionation.

Comparison of the results obtained in the present work with the results of benzene [10] and chlorobenzene [1] alkylation leads to certain conclusions on the effect of the halogen attached to the benzene ring on the alkylation reaction.

In Table 1 is given a comparison of the yields of alkylbenzenes and alkyl- bromo- and alkylchlorobenzenes, obtained at a benzene : alkyl halide ratio of 6 : 1 in the presence of 0.01 g-at of aluminum metal per mole of alkyl halide.

TABLE 1

Name of alkylation product	Yields of alkylation products (in %)		
	R = C ₂ H ₅	R = iso-C ₃ H ₇	R = iso-C ₄ H ₉
Alkylbenzene RC ₆ H ₅	58	76	83
Alkylbromobenzene RC ₆ H ₄ Br	35	66	70
Alkylchlorobenzene RC ₆ H ₄ Cl	33	53	62

From the data presented it follows that, as would be expected, the presence of a halogen in the benzene ring produces a fall in the yields of alkylation products. *n*-Propyl- and *n*-butylbromobenzenes were not isolated from the alkylation products. These observations agree well with literature data on the relatively great stability of carbonium ions with an iso-structure [11] and with contemporary views on the alkylation of aromatic compounds with alkyl halides as an electrophilic substitution reaction accomplished by an ionic-carbonium mechanism.

EXPERIMENTAL

The starting materials were carefully dried, distilled immediately before an experiment and had constants agreeing with literature data. The aluminum metal was used in the form of freshly cut turnings [1, 10]. Experiments were performed with various ratios of bromobenzene and alkyl halides, but in all cases, 0.01 g-at of aluminum was used per mole of alkyl bromide. At first only part of a previously prepared mixture of bromobenzene and alkyl bromide was introduced into the reaction. The reaction mixture was heated to boiling (120-140°) and then the reaction began, as could be judged by the appearance of separate bubbles of hydrogen bromide and the change in color of the reaction mixture. After this, heating was stopped and the rest of the reagents introduced by means of a dropping funnel. The initiated reaction developed vigorously as the aluminum metal was converted into an active state and was accompanied by copious evolution of hydrogen bromide and a noticeable fall in the reaction-mixture temperature. The reaction was completed by heating the mixture for 30-40 minutes at 80°.

The catalyzate, a dark-brown liquid, was decanted from unreacted aluminum, treated with dilute hydrochloric acid, water, alkali and again water, dried and fractionated. Distillation of the alkylation products obtained from each individual experiment yielded five fractions: 1st - benzene, formed as a result of the disproportionation of bromobenzene (b. p. 80°, *n*_D²⁰ 1.5015, *d*₄²⁰ 0.8792); 2nd - excess bromobenzene (b. p. 156°, *n*_D²⁰ 1.5605, *d*₄²⁰ 1.4957); 3rd (main fraction) - alkylation product; 4th - *p*-dibromobenzene - the disproportionation product of bromobenzene (m. p. 87.5°; literature data [12]: m. p. 87.31°); the 5th fraction, consisting of polyalkylbromobenzenes, was not examined in detail. The purification of the alkylbromobenzenes was considerably complicated by the presence of *p*-dibromobenzene with b. p. 79-80° (5 mm), which is close to the boiling point of the alkylbromobenzenes (Table 3). For purification, the main fraction was cooled to -20° and the dibromobenzene which crystallized was rapidly collected by filtration in an externally cooled funnel. This operation was repeated until *p*-dibromobenzene ceased to separate. The alkylbromobenzene was then distilled in vacuum on a column of 30 theoretical plates with a glass packing.

In the alkylation of bromobenzene in the presence of aluminum remaining from a previous experiment (activated), the reaction began at 60-70° and developed rapidly and uniformly at 80°. In this case there was less

disproportionation of the bromobenzene and the separation of the reaction products was noticeably facilitated.

The structure of the alkylation products was determined by oxidation with nitric acid according to Meyer's method [13] (according to literature data, *o*-bromobenzoic acid melts at 148.9° [14], *p*-bromobenzoic acid at 255-256° [15] and *m*-bromobenzoic acid at 154° [16]) and by the preparation of perbromination products.

Hennion and Anderson [17] showed that an alkyl group of normal structure, attached to a benzene ring, may be distinguished from secondary and tertiary ones by bromination in the presence of aluminum bromide; during bromination, secondary and tertiary radicals are eliminated and hexabromobenzene is obtained; side chains of normal structure are not eliminated and bromination yields the corresponding pentabromobenzenes. The yields of the alkylation products were calculated on the alkyl halide taken for the reaction.

Effect of the nature of the alkyl bromides and the ratio of the reacting components on the yields of alkylbromobenzenes. Experiments were performed with different molar ratios of bromobenzene and alkyl bromides (Table 2).

The alkylation of bromobenzene with ethyl bromide differed slightly from the alkylation of bromobenzene with *n*-propyl and *n*-butyl bromides: the induction period lasted for 30-40 minutes instead of 2-15 minutes as with *n*-propyl and *n*-butyl bromides; the aluminum metal dissolved in the reaction mixture completely; bromobenzene was disproportionated to a greater extent.

In the alkylation of bromobenzene with ethyl bromide, molar ratios of bromobenzene : ethyl bromide of from 2 : 1 to 6 : 1 were used (Table 2). Careful purification of the third fraction to remove dibromobenzene and

distillation on a column yielded *o*- and *p*-ethylbromobenzene. We then prepared the products of their oxidation, *o*- and *p*-bromobenzoic acids with *m. p.* 148 and 256° and the perbromination product, pentabromoethylbenzene with *m. p.* 136-136.5°; according to the data of Hennion [18], pentabromoethylbenzene melts at 137-138.5°. The results obtained in this series of experiments and corresponding literature data are presented in Table 3.

Bromobenzene was alkylated with *n*-propyl and *n*-butyl bromides both with freshly cut aluminum metal and with that remaining from a previous experiment (activated). The reagents were used in ratios of from 1 : 1 to 7 : 1 (Table 2).

Careful purification of the main fraction obtained from bromobenzene alkylation with *n*-propyl bromide and its distillation on a column yielded *p*-isopropylbromobenzene. Oxidation of this gave *p*-bromobenzoic acid (*m. p.*

255°) and bromination, hexabromobenzene with *m. p.* 317° [17]. The constants of the *p*-isopropylbromobenzene obtained and literature data are presented in Table 3.

The alkylation of bromobenzene with *n*-butyl bromide gave isobutylbromobenzene. As in the previous case, oxidation of this yielded *p*-bromobenzoic acid (*m. p.* 255°) and bromination, hexabromobenzene (*m. p.* 317°).

On the basis of the properties of the oxidation and bromination products of the isobutylbromobenzene obtained, it may be concluded that the latter was the *p*-isomer. However, due to the absence of literature data on the constants of the bulk of *o*- and *p*-isobutylbromobenzenes, no conclusion could be drawn on the structure of the alkyl group in it. We did not study this problem in the present work.

The constants of the isobutylbromobenzene obtained and available literature data are presented in Table 3.

Effect of reaction mixture heating time on the yield of alkylation products. Bromobenzene was alkylated with ethyl bromide at a reagent ratio of 3 : 1 and with *n*-propyl and *n*-butyl bromides at a ratio of 5 : 1. The experiments were completed by heating the reaction mixture at 80°. The results of the experiments are presented in Table 4.

TABLE 2

Molar ratio bromoben- zene: alkyl bromide	Yields of alkylation products (in %)		
	ethyl- bromo- benzene	isopropyl- bromo- benzene	isobutyl- bromo- benzene
1 : 1	—	42	40
2 : 1	43	—	54
3 : 1	52	58	59
4 : 1	47	65	67
5 : 1	40	68-75 *	72-80 *
6 : 1	35	66	70
7 : 1	—	64	68

TABLE 3

Name of substance	Data	Boiling point (pressure in mm)	n_D^{20}	d_4^{20}	% C		% H		% Br	
					found	calc.	found	calc.	found	calc.
o-Ethylbromobenzene	Ours	74.5 (9)	1.5485	1.3583	51.72	54.91	4.92	4.90	43.16	43.18
p-Ethylbromobenzene	Ours	78.5 (11)	1.5449	1.3425	51.79	—	4.87	4.90	43.20	43.18
o-Ethylbromobenzene	[12] [12]	201.5 (760)	1.54872	1.3583	—	—	—	—	—	—
p-Ethylbromobenzene	[12] [12]	205.07 (760)	1.54475	1.3425	—	—	—	—	—	—
p-Isopropylbromobenzene	Ours	84.7 (10)	1.5368	1.2850	53.75	54.29	5.31	5.56	40.81	40.13
p-Isopropylbromobenzene	[12] [12]	218.7 (760)	1.53601	1.2854	—	—	—	—	—	—
o-Isopropylbromobenzene	[12] [12]	210.24 (760)	1.54084	1.30195	—	—	—	—	—	—
Isobutylbromobenzene	Ours	102.9 (11)	1.5311	1.2378	56.16	56.40	6.12	6.14	37.46	37.49
p-Tert.-butylbromobenzene	[19] [20]	103 (10)	1.5268*	1.2283*	—	—	—	—	—	—
p-Sec.-butylbromobenzene	[20] [21]	94 (4)	1.5340	1.2605	—	—	—	—	—	—
Mixture of p-bromobutylbenzenes	[21]	105—109 (13)	1.5330	1.2527	—	—	—	—	—	—

* At 30°.

Effect of reaction mixture temperature on the yield of alkylation products. The experiments were performed at the same ratios as in the previous case and concluded by heating the reaction mixture for 40 minutes at various temperatures. The results are presented in Table 5.

Alkylation of Iodobenzene with n-Butyl Bromide

Iodobenzene was alkylated with n-butyl bromide at a reagent ratio of 5:1. In the presence of freshly cut aluminum, the reaction began 4-5 minutes after the reaction mixture began to boil and

TABLE 4

Duration of heating of reaction mixture	Yields of alkylation products (in %)		
	ethyl-bromo-benzene	isopropyl-bromo-benzene	isobutyl-bromo-benzene
40 min	52	68	72
1 hour	45	55	70
4 hours	40	40	65

TABLE 5

Reaction mixture temperature	Yields of alkylation products (in %)		
	ethyl-bromo-benzene	isopropyl-bromo-benzene	isobutyl-bromo-benzene
80°	52	68	72
110	38	60	65
140	23	48	53

was accompanied by the intense evolution of violet iodine vapor; the reaction mixture darkened, tar formed and the reaction rapidly died out. The catalyze consisted of iodine, benzene (b. p. 80°, n_D^{20} 1.5012, d_4^{20} 0.8793), unreacted iodobenzene [b. p. 65° (11 mm), n_D^{20} 1.6211, d_4^{20} 1.83481], butylbenzene (b. p. 168°, n_D^{20} 1.4921, d_4^{20} 0.8650), p-diiodobenzene (b. p. 128°) and tarry products. The amount of benzene, butylbenzene and p-diiodobenzene was small in comparison with the amount of tarry products. When activated aluminum was used, the reaction began at room temperature, was accompanied by considerable heat evolution and due to

this, the reaction mixture had to be cooled. This main reaction products were benzene, butylbenzene, p-di-iodobenzene and tarry products.

SUMMARY

1. Bromobenzene was alkylated with ethyl bromide, n-propyl bromide and n-butyl bromide in the presence of aluminum metal.
2. The yields of alkylbromobenzenes increased with an increase in the molecular weight of the alkyl bromides. The maximum yield of ethylbromobenzene (mixture of para- and ortho-isomers) was 52%, of p-isopropylbromobenzene, 75% and of p-isobutylbromobenzene, 80%.
3. Alkylbromobenzenes of normal structure were not obtained.
4. Iodobenzene could not be alkylated with n-butyl bromide in the presence of aluminum metal.

LITERATURE CITED

- [1] M. B. Turova-Polyak and M. A. Maslova, *J. Gen. Chem.* 27, 897 (1957).*
- [2] J. F. Spencer and M. L. Wallach, *J. Chem. Soc.*, 93, 1827 (1908).
- [3] V. Grignard and J. Jenkins, *Bull. Soc. Chim.*, [4], 37, 1376 (1925).
- [4] P. Leone, *Atti acad. Lincei*, [5], 33, 11, 497 (1924); *Ch. A.*, 19, 2920 (1925).
- [5] A. Grosse and J. M. Mavity, *J. Org. Ch.* 5, 107 (1940).
- [6] F. Quincke, *Z. phys. Ch.*, 3, 164 (1889).
- [7] E. Louise and L. Roux, *Bull. Soc. Chim.* [2], 50, 497 (1888).
- [8] O. Dumreicher, *Ber.*, 15, 1866 (1882).
- [9] G. Baddeley and J. Plant, *J. Chem. Soc.*, 1943, 525.
- [10] M. B. Turova-Polyak and M. A. Maslova, *J. Gen. Chem.* 26, 2185 (1956).*
- [11] A. G. Evans, M. Polanyi, *J. Chem. Soc.*, 1947, 252.
- [12] R. R. Dreisbach, and R. A. Martin, *Ind. Eng. Ch.*, 41, 2875 (1949).
- [13] R. Meyer, *J. pr. Ch.*, [2], 34, 94 (1886).
- [14] B. C. Barton and C. A. Kraus, *J. Am. Chem. Soc.*, 73, 4561 (1951).
- [15] M. R. Snyder and G. R. Handrick, *J. Am. Chem. Soc.*, 66, 1860 (1944).
- [16] B. M. Bogoslovskii and T. I. Yakovenko, *J. Gen. Chem.*, 24, 1043 (1954).*
- [17] G. F. Hennion and J. G. Anderson, *J. Am. Chem. Soc.*, 66, 1801 (1944).
- [18] G. F. Hennion and J. G. Anderson, *J. Am. Chem. Soc.*, 68, 424 (1946).
- [19] G. J. Legge, *J. Am. Chem. Soc.*, 69, 2086 (1947).
- [20] J. W. Copenhaver, M. F. Roy, and C. S. Marvel, *J. Am. Chem. Soc.*, 57, 1311 (1935).
- [21] V. D. Azatyan, *Proc. Acad. Sci. Armenian SSR*, 25, 235 (1957).

Received March 6, 1958

*Original Russian pagination. See C.B. Translation.

ISOMERIZATION OF POLYMETHYLENE HYDROCARBONS UNDER THE ACTION OF ALUMINUM CHLORIDE

XXIII. ISOMERIZATION OF 2-METHYL-BICYCLO-(1,2,2)-HEPTANE

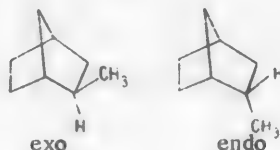
M. B. Turova-Polyak, I. E. Sosnina, I. G. Golutvina
and T. P. Yudkina
Moscow State University

The catalytic conversions of bicyclic bridged hydrocarbons in the presence of aluminum chloride have not been studied up to now. Only very recently did a paper appear by Schlever [1], who obtained adamantane by the action of aluminum chloride on endo-trimethylenenorbornane (tetrahydrodicyclopentadiene) due to isomerization of the rings.

The basis of many natural substances is formed by the skeleton of bicyclo-(1,2,2)-heptane and therefore a study of hydrocarbons of this series is of definite interest.

The molecule of 2-methyl-bicyclo-(1,2,2)-heptane is formed from two five-membered rings, one of which contains a methyl group. The basis of the molecule is a six-membered ring, which, however, does not possess the characteristic capacity of cyclohexane for dehydrogenation, according to the data of B. A. Kazanskii, A. V. Koperina and M. I. Batuev [2]. The methylene bridge rigidly fixes the cyclohexane part of the molecule in a cis-position, which corresponds to the maximum potential energy. In addition, due to the deviation of the valence angles from the tetrahedral values, the molecule of 2-methyl-bicyclo-(1,2,2)-heptane is under great strain [3].

It is known that the theoretically possible endo- and exo-isomers of 2-methyl-bicyclo-(1,2,2)-heptane have not been isolated in an individual state up to now.



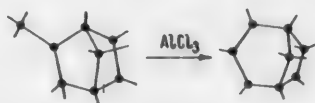
The transition of similar steric configurations of hydrocarbons was observed by Schlever [1] in the action of aluminum chloride on endo-trimethylenenorbornane.

As a result of our investigations, it was found that on reaction with aluminum chloride at 75°, 2-methyl-bicyclo-(1,2,2)-heptane was practically completely isomerized into bicyclo-(1,2,2)-octane, a system formed from a five- and a six-membered ring, whose basis is a seven-membered ring.

At 100°, this reaction was accompanied by the formation of condensation products. At 21-28°, one steric configuration of 2-methyl-bicyclo-(1,2,2)-heptane was converted into the other, as was confirmed by both spectral analysis and the physical constants.

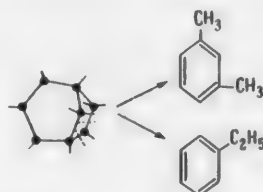
Despite the complexity of the 2-methyl-bicyclo-(1,2,2)-heptane molecule, its conversion into bicyclo-

(1,2,3)-octane can be visualized by considering the behavior of the rings forming the molecule of the original hydrocarbon in the presence of aluminum chloride. It is known that under the action of aluminum chloride, cyclopentane is not changed [4], while methylcyclopentane is isomerized into cyclohexane [5]. On this basis, the isomerization of 2-methyl-bicyclo-(1,2,2)-heptane into bicyclo-(1,2,3)-octane may be explained by enlargement of the cyclopentane ring containing the methyl group into a cyclohexane ring.



The presence of bicyclo-(1,2,3)-octane in the reaction product was confirmed by its behavior under hydrogenolysis conditions.

In analogy with the hydrogenolysis of bicyclo-(1,2,2)-heptane, investigated by B. A. Kazanskii [2], the hydrogenolysis of bicyclo-(1,2,3)-octane must proceed with the formation of mainly dimethylcyclohexane and partially ethylcyclohexane. These hydrocarbons must then dehydrogenate to xylene and ethylbenzene.

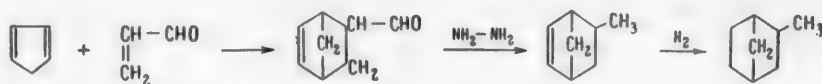


Hydrogenolysis of the isomerization product of 2-methyl-bicyclo-(1,2,2)-heptane formed m-xylene, which was identified in the form of 2,4,6-trinitro-m-xylene [6]; in addition, oxidation of the catalyzate yielded isophthalic acid. Ethylbenzene could not be detected in the hydrogenolysis product.

From the results obtained in the present work, we may arrive at the conclusion that in the presence of aluminum chloride, that part of the 2-methyl-bicyclo-(1,2,2)-heptane molecule which corresponds to methylcyclopentane behaves as in the isolated state, i.e., it is enlarged to a six-membered ring; under the given conditions, the bicyclo-(1,2,3)-octane system is less strained and more stable than the bicyclo-(1,2,2)-heptane system, and the seven-membered ring forming the basis of the bicyclo-(1,2,3)-octane does not show its properties just as the six-membered ring in bicyclo-(1,2,2)-heptane does not [2].

EXPERIMENTAL

2-Methyl-bicyclo-(1,2,2)-heptane was obtained by the reaction of cyclopentadiene with acrolein according to the procedure of N. D. Zelinskii, B. A. Kazanskii and A. F. Platé [7], with the difference that the 2-methyl-bicyclo-(1,2,2)-heptene-5-, obtained in the course of the synthesis, was hydrogenated not in the presence of platinized charcoal, but in the presence of skeletal nickel, incompletely extracted with alkali [8].



Chromatographic purification on silica gel yielded 2-methyl-bicyclo-(1,2,2)-heptane.

B. p. 125.8-126.8° (755 mm), n_D^{20} 1.4540, d_4^{30} 0.8535, MRD 34.90. C_8H_{14} . Calculated 34.74.

Literature data [7] for 2-methyl-bicyclo-(1,2,2)-heptane: b. p. 125.126.5° (715.5 mm), n_D^{20} 1.4535, d_4^{30} 0.8532, MRD 34.92.

Distillation of the 2-methyl-bicyclo-(1,2,2)-heptane on a fractionation column with an efficiency of 80 theoretical plates yielded 10 fractions, whose constants are given in Table 1.

From a comparison of the constants presented in the table it follows that the hydrocarbon we obtained, which boiled over a one-degree range, was not an individual substance, despite the fact that analysis of the first and tenth fraction gave concurring results, corresponding to the calculated value.

1st fraction. Found %: C 87.16; H 13.00. 10th fraction. Found %: C 87.10; H 13.05. C_8H_{14} .
Calculated %: C 87.19; H 12.81.

In addition, the Raman spectrum of the 1st fraction differed from the Raman spectrum of the 10th fraction (see Table 3).

TABLE 1

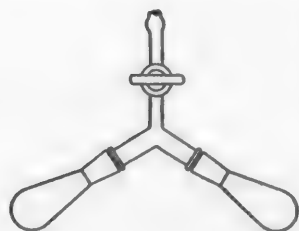
Fraction	Boiling point (at 750 mm)	Amount (in ml)	n_D^{20}	d_4^{20}	MR_D^*
1	125.5°	11.5	1.4531	0.8532	34.84
2	125.5—125.6	11.5	1.4531	0.8532	34.84
3	125.6—125.7	3.6	1.4531	0.8532	34.84
4	125.7—125.8	6.2	1.4531	0.8533	34.85
5	125.8—126.0	5.0	1.4540	0.8540	34.86
6	126.0—126.1	9.5	1.4540	0.8550	34.85
7	126.1—126.2	8.4	1.4545	0.8558	34.85
8	126.2—126.3	6.0	1.4550	0.8572	34.85
9	126.3—126.4	5.2	1.4550	0.8572	34.85
10	126.4—126.5	15.5	1.4555	0.8588	34.78

* The MR_D calculated for C_8H_{14} is 34.74.

From the work of K. Alder [9], it is known that the reaction of cyclopentadiene with acrolein gives predominantly endomethyltetrahydrobenzaldehyde. Conversion of the latter into 2-methyl-bicyclo-(1,2,2)-heptene-5 via the hydrazone of endomethyltetrahydrobenzaldehyde, apparently is not accompanied by a change in configuration of the hydrocarbon. According to literature data [7], this conversion depends on the conditions of 2-methyl-bicyclo-(1,2,2)-heptene-5 hydrogenation; hydrogenation in the presence of platinum at 130° yields an isomeric mixture of hydrocarbons, boiling over four degrees (120–124°); according to the data of [7], hydrogenation of 2-methyl-bicyclo-(1,2,2)-heptene-5 in the cold in the presence of palladium gives a more homogeneous 2-methyl-bicyclo-(1,2,2)-heptane with b. p. 124.5–126°.

From an analysis of data on the fractional distillation (Table 1), elementary analysis and Raman spectra obtained in this work and literature data [10] it follows that the 2-methyl-bicyclo-(1,2,2)-heptane, which we obtained by hydrogenation of the unsaturated hydrocarbon in the presence of skeletal nickel, like that obtained previously by N. D. Zelinsky, B. A. Kazanskii and A. F. Platé in the presence of palladium, was not an individual compound and consisted of a mixture of exo- and endo-isomers. The first four fractions of the hydrocarbon we isolated (Table 1), were enriched in one form of 2-methyl-bicyclo-(1,2,2)-heptane, while the rest of the fractions were a mixture with an increasing amount of the other form of this hydrocarbon.

For studying the isomerizing action of aluminum chloride on 2-methyl-bicyclo-(1,2,2)-heptane, two series of experiments were performed: one with the combined fractions 1–4, whose constants are close to each other (A), and the other with the combined fractions 5–10 (B). In all experiments the hydrocarbon and aluminum chloride were reacted in a molar ratio of 3:1 and kept in contact for 10–12 hours. The reaction was carried out in a two-necked flask, fitted with a reflux condenser connected to a Tishchenko bottle with sulfuric acid and a thermometer reaching almost to the bottom of the flask. No gaseous products were liberated during the reaction and the aluminum chloride was unchanged externally.



Apparatus for drying and subliming hydrocarbons.

Experiments 1-A and 1-B were at 21° (room temperature). While in experiment 1-A the temperature only rose to 23°, in experiment 1-B it immediately rose to 28° and then fell to room temperature. After the experiment, the hydrocarbon layer was separated from the aluminum chloride, washed, dried and distilled over metallic sodium (Table 2).

As the data in Table 2 show, in experiment 1-A the constants of the reaction product changed little as compared with the constants of the original hydrocarbon A. In experiment 1-B, the constants of the isomerization product indicated that changes had occurred in the original hydrocarbon. The constants of the isomerization products of hydrocarbon B were close to those of hydrocarbon A. The Raman spectra also changed in the same direction (Table 3).

Thus, it can be considered proved that under the action of aluminum chloride at 21-28°, hydrocarbon B is isomerized into hydrocarbon A and that under these conditions, one form of 2-methyl-bicyclo-(1,2,2)-heptane is converted into the other.

TABLE 2

Hydrocarbons	Boiling point	n_D^{20}	d_4^{20}	MR_D^*
Hydrocarbon* A (combined fractions 1-4, Table 1)	125.5—125.8°	1.4531	0.8532	34.85
Isomerization product**	123—124.5	1.4525	0.8525	34.84
Hydrocarbon* B (combined fractions 5-10, Table 1)	125.8—126.5	1.4550	0.8565	34.89
Isomerization product**	123—124	1.4536	0.8529	34.89

* The MR_D calculated for C_8H_{14} is 34.74.

** Crystalline products were not formed on cooling to 0°.

Experiments II-A and II-B were performed at 75° and proceeded quite identically. During the course of the reaction, the reaction product sublimed and a dense, crystalline mass was deposited on the cold walls of the flask. After the reaction, a very small amount of liquid product was separated from the solid hydrocarbon cooled to 0° and this was distilled at 130-135° and was apparently the original hydrocarbon with traces of isomerization product. The crystalline hydrocarbons obtained from the two experiments were twice dissolved in alcohol and precipitated with water [11]. The hydrocarbon was dried and sublimed in the apparatus illustrated in the figure.

Into one of the flasks was placed the crystalline hydrocarbon, mixed with phosphorus pentoxide, the flask cooled with liquid nitrogen, the air pumped from the apparatus to a vacuum of 10^{-2} mm, the tap closed, the coolant removed and the hydrocarbon dried for 24 hours. The empty flask was then cooled and without any heating, the hydrocarbon rapidly sublimed. The bicyclo-(1,2,3)-octane obtained as a result of 30 sublimations melted at 140-141°.

The constants for bicyclo-(1,2,3)-octane available in the literature differ from each other. This is apparently explained by a difference in its degree of purity. Thus, Barrett and Linstead [11], Komppa, Hirn et al. [12] report m. p. 133° for bicyclo-(1,2,3)-octane; Alder and Windemuth [13], 141° and Doering and Faber [14], 139.5-141°.

Combined fractions B only were used for experiment III.

Besides the solid hydrocarbon with m. p. 140°, a greater amount of the liquid reaction products than in the previous experiments was obtained. Careful distillation of it yielded a fraction with b. p. 200-265°, n_D^{20} 1.4778, d_4^{20} 0.9077, apparently containing products of deeper condensation. These products were not investigated in more detail.

The bicyclo-(1,2,3)-octane obtained from experiments II-A and II-B was hydrogenolyzed over platinized charcoal at 300-310° in a stream of hydrogen. For this, bicyclo-(1,2,3)-octane was placed in the front part of a catalytic tube and slowly moved into the furnace. Three passes over the catalyst gave a catalyzate with n_D^{20} 1.4800, from which we obtained 2,4,6-trinitro-m-xylene [6] with m. p. 181°. A mixed melting point of this with synthetic 2,4,6-trinitro-m-xylene was not depressed. Oxidation of the catalyzate with permanganate by Ulmann's method [15] yielded isophthalic acid with m. p. 346-347°.

TABLE 3

Hydrocarbon A		Hydrocarbon B	
before experiment	after experiment	after experiment	before experiment
268 (0.8)	268 (1)	268 (1)	
299 (0.5)	299 (0)	317 (0.5)	
397 (3; d)	397 (1.5)	397 (1)	397 (1.5)
406 (3; d)	406 (1.5)	406 (0.5)	406 (1)
		414 (0)	
435 (2.5)	435 (1.5)	435 (0)	
466 (0.5)		460 (0)	
484 (0.8)	484 (0)	484 (2)	484 (4)
580 (1)	580 (4)	580 (6)	
657 (0)			660 (0; b)
721 (9)	721 (10)	721 (10)	721 (40)
		735 (0)	
757 (1.5)	757 (3; d)	757 (4)	757 (0)
	775 (1.5)	775 (2)	
792 (2.5)	792 (1.5; d)	792 (2)	792 (3)
822 (0.8)	822 (0.5)	822 (3.5)	822 (8)
833 (12)	833 (15)	833 (1.5)	
			846 (0)
	855 (1)	855 (6)	
872 (3)	871 (2.5)	872 (3.5)	875 (6)
897 (7)	897 (5)	897 (7)	897 (20)
923 (40)	923 (35)	923 (12; b)	923 (20)
			930 (20)
948 (4)	948 (3)	948 (3.5)	948 (4)
970 (10)	970 (7)	970 (8)	970 (10)
991 (1; d)			991 (1; db)
1020 (0.5)	1014 (0.5)	1014 (1)	1020 (5)
1032 (12)	1032 (12)	1032 (2; d)	
1057 (0)	1057 (0)	1057 (2)	1057 (4)
1070 (2.5; d)	1073 (2)	1073 (0.5)	1079 (1.5)
1104 (8)	1104 (5)	1104 (8; d)	1104 (8; d)
1117 (10)	1117 (10)		1117 (8; d)
1133 (0)			1133 (7)
1144 (7)	1144 (3)	1144 (0)	
1160 (0.5)	1162 (1)		
1179 (4; b)	1178 (3)	1178 (5; d)	
1186 (3; d)			1183 (9; d)
1197 (0.5; d)	1196 (2)		1197 (0)
1220 (2)	1226 (0.5)		1219 (1)
1244 (0.8)	1248 (1; d)	1251 (1; d)	1241 (0)
1309 (1)	1303 (0)	1303 (0)	1309 (2.5; d)
			1323 (0.5)
1347 (1)	1347 (0)	1347 (0)	1347 (2)
1370 (0.5; d)	1370 (0)	1372 (0)	1372 (0.5)
	1389 (0)		
1443 (10; b)	1443 (10)	1443 (10)	1443 (10; b)
1460 (7)			
1477 (0.5)	1477 (0)	1477 (0)	1477 (0.5)

Note: b = broad, d = diffuse, db = double.

SUMMARY

1. A study was made of the isomerization of 2-methyl-bicyclo-(1,2,2)-heptane under the action of aluminum chloride.

2. The synthesis of 2-methyl-bicyclo-(1,2,2)-heptane by condensation of cyclopentadiene with acrolein and hydrogenation of 2-methyl-bicyclo-(1,2,2)-heptene-5 in the presence of skeletal nickel yielded a mixture of exo- and endoisomers of 2-methyl-bicyclo-(1,2,2)-heptane.

3. At 21°, aluminum chloride promoted the transition of one form of 2-methyl-bicyclo-(1,2,2)-heptane into the other; at 75°, aluminum chloride produced isomerization of 2-methyl-bicyclo-(1,2,2)-heptane into bicyclo-(1,2,3)-octane; at 100°, high-boiling condensation products were formed together with bicyclo-(1,2,3)-octane.

4. Hydrogenolysis of bicyclo-(1,2,3)-octane gave m-xylene.

LITERATURE CITED

- [1] P. R. Schlever, J. Am. Chem. Soc., 79, 3292 (1957).
- [2] B. A. Kazanskii, A. V. Koperina and M. I. Batuev, Proc. Acad. Sci. USSR, 62, 337 (1948).
- [3] W. Hüchel, Lieb. Ann., 445, 123 (1927).
- [4] M. Cox, Bull. Soc. Chim, 37, 1549 (1925).
- [5] M. B. Turova-Polyak and N. B. Baranovskaya, J. Gen. Chem., 9, 429 (1939).
- [6] B. A. Kazanskii and A. L. Liberman, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1947, 266.
- [7] N. D. Zelinskii, B. A. Kazanskii and A. F. Platé, J. Gen. Chem., 4, 168 (1934).
- [8] M. B. Turova-Polyak, Z. S. Kraits and E. G. Treshchova, J. Gen. Chem., 26 2734 (1956).
- [9] K. Alder and G. Stein, Lieb. Ann., 514, 197 (1934).
- [10] V. T. Aleksanyan and Kh. E. Sterin, Material of the X All-Union Conference on Spectroscopy, Vol. I. Molecular Spectroscopy, p. 59 (1957).

[11] J. W. Barrett and R. P. Linstead, J. Chem. Soc., 1936, 611.

[12] G. Komppa, T. Hirn, W. Rohrmann, and S. Beckmann, Lieb. Ann., 521, 242 (1936).

[13] K. Alder and E. Windemuth, Ber., 71, 2404 (1938).

[14] W. E. Doering, and M. Farber, J. Am. Chem. Soc., 71, 1514 (1949).

[15] F. Ulmann, and J. Uzbachian, Ber., 36, 1798 (1903).

*Original Russian pagination. See C.B. Translation.

Received February 11, 1958

ETHYLENE SULFIDE IN THE SYNTHESIS OF HETEROCYCLIC COMPOUNDS WITH TWO HETERO ATOMS

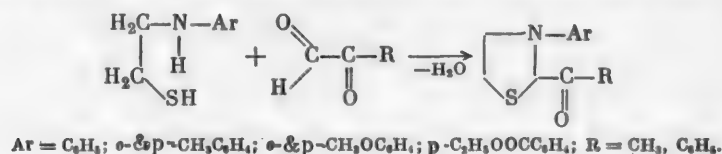
IX. SYNTHESIS OF 2-ACYL-2-ARYLTHIAZOLIDINES

Yu. K. Yur'ev and S. V. Dyatlovitskaya

Moscow State University

In our previous work it was shown that the condensation of N-(β -mercaptoethyl)-arylamines with aliphatic, aromatic and heterocyclic aldehydes is a convenient method of synthesizing 3-arylthiazolidines with alkyl, aryl or other radicals in position 2 of this ring [1-4]. In contrast to aldehydes, which react with β -mercaptoethylamines in the cold, ketones react only on prolonged heating [5]. Therefore, one would expect that under certain conditions α -ketoaldehydes would react with N-(β -mercaptoethyl)-arylamines predominantly through its aldehyde group and thus it would be possible to synthesize previously unknown ketones of the thiazolidine series containing a carbonyl group in position 2. Up to now this type of ketone (with an acetyl or an acetyl group in position 2 of the thiazolidine ring) has only been described for the thiazolidine-4-carboxylic acid series [6].

In the present work we condensed methylglyoxal and phenylglyoxal with N-(β -mercaptoethyl)-arylamines and obtained a series of 2-acetyl- and 2-benzoyl-3-arylthiazolidines in 41-95% yields.



The infrared absorption spectra of the 2-acyl-3-arylthiazolidines obtained in this way showed a maximum in the region 1710-1705 cm⁻¹, corresponding to the absorption band of the carbonyl group [7].

The ketones of the 2-acyl-3-arylthiazolidine series we obtained underwent certain reactions characteristic of ketones with very great difficulty, apparently due to steric hindrance; they did not react with semicarbazide or thiosemicarbazide even on prolonged heating. We were able to obtain semicarbazones in the presence of iodine and glacial acetic acid (as described by Gever et al. [8] for the condensation of 5-nitro-2-acetylfuran with 3-aminoxazolidone-2), but only for ketones with substituents in the para position of the benzene nucleus attached to the nitrogen of the thiazolidine ring; the corresponding ortho isomers did not react, even under these conditions.

An attempt to prepare oximes of these ketones was unsuccessful; when the ketones were boiled with hydroxylamine hydrochloride in an alkaline medium, destruction of the thiazolidine ring occurred and was indicated by the appearance of a positive reaction for a sulfhydryl group.

EXPERIMENTAL*

Synthesis of 2-Acetyl-3-arylthiazolidines

0.01 mole of N-(β -mercaptoethyl)-arylamine in 5 ml of anhydrous alcohol was mixed with 0.03 mole of methylglyoxal in 3 ml of anhydrous alcohol, at which the mixture evolved heat. The mixture was heated to boiling and poured with stirring onto crushed ice (50 g). The oil that was liberated crystallized on standing; the crystals of ketone were collected, dried and recrystallized from 80% alcohol.

For the preparation of semicarbazones of 2-acetyl-3-arylthiazolidines, a mixture of 0.001 mole of ketone and 0.001 mole of semicarbazide (base) was boiled for 30-40 minutes in 3 ml of anhydrous alcohol in the presence of 2 drops of glacial acetic acid and a small crystal of iodine. The precipitated semicarbazone crystals were collected (solution cooled) and recrystallized from alcohol.

2-Acetyl-3-phenylthiazolidine. From 1.53 g of N-(β -mercaptoethyl)-aniline and 2.16 g of methylglyoxal we obtained 1.99 g (96.0%) of ketone with m. p. 57.5-58°.

Found %: C 63.86, 63.87; H 6.49, 6.46; N 7.13, 7.14. $C_{11}H_{11}ONS$. Calculated %: C 63.73; H 6.32; N 6.76.

Semicarbazone with m. p. 203-204°.

Found %: N 21.32. $C_{12}H_{12}ON_4S$. Calculated %: N 21.20.

2-Acetyl-3-p-tolylthiazolidine. From 1.67 g of N-(β -mercaptoethyl)-p-toluidine and 2.16 g of methylglyoxal, we obtained 2.22 g (quantitative yield) of ketone with m. p. 65.5-66°.

Found %: C 65.15, 65.01; H 6.82, 7.06; N 6.23, 6.35. $C_{12}H_{13}ONS$. Calculated %: C 65.12; H 6.83; N 6.33.

Semicarbazone with m. p. 204-205°.

Found %: N 19.73, 19.95. $C_{13}H_{13}ON_4S$. Calculated %: N 20.13.

2-Acetyl-3-p-anisylthiazolidine. From 1.83 g of N-(β -mercaptoethyl)-p-anisidine and 2.16 g of methylglyoxal, we obtained 1.19 g (50%) of ketone with m. p. 74-74.5°.

Found %: C 60.85, 60.90; H 6.50, 6.45; N 6.00, 6.06. $C_{13}H_{15}O_2NS$. Calculated %: C 60.73; H 6.37; N 5.90.

Semicarbazone with m. p. 190-191°.

Found %: N 19.16, 19.35. $C_{13}H_{15}O_2N_4S$. Calculated %: N 19.03.

2-Acetyl-3-o-anisylthiazolidine. From 1.83 g of N-(β -mercaptoethyl)-o-anisidine and 2.16 g of methylglyoxal we obtained 2.14 g (90.5%) of ketone with m. p. 98.5-99°.

Found %: C 60.75, 60.84; H 6.46, 6.46; N 5.85, 6.03. $C_{13}H_{15}O_2NS$. Calculated %: C 60.73; H 6.37; N 5.90.

2-Acetyl-3-p-carbethoxyphenylthiazolidine. From 2.25 g of N-(β -mercaptoethyl)-p-carbethoxyaniline and 2.16 g of methylglyoxal we obtained 1.8 g (64.0%) of ketone with m. p. 70.5-71°.

Found %: C 60.44, 60.53; H 6.28, 6.25; N 5.17, 5.11. $C_{14}H_{17}O_3NS$. Calculated %: C 60.18; H 6.13; N 5.01.

Semicarbazone with m. p. 203-203.5°.

Found %: N 16.47. $C_{15}H_{20}O_3N_4S$. Calculated %: N 16.66.

Synthesis of 2-Benzoyl-3-arylthiazolidines

2-Benzoyl-3-phenylthiazolidine. To 1.53 g (0.01 mole) of N-(β -mercaptoethyl)-aniline in 5 ml of anhydrous alcohol was added 5.36 g (0.04 mole) of phenylglyoxal in 2 ml of anhydrous alcohol; the mixture gave off heat. On cooling it yielded 2.66 g (quantitative yield) of ketone in the form of yellow needles with m. p. 126-126.5° (from alcohol).

* With the participation of student I. G. Bulavin.

Found %: C 71.43, 71.30; H 5.89, 5.79; N 5.01, 5.10. $C_{16}H_{15}ONS$. Calculated %: C 71.30; H 5.62; N 5.20.

The semicarbazone, obtained as indicated above, was washed repeatedly with boiling water and hot alcohol; the m. p. was 223-224°.

Found %: N 16.97, 16.84. $C_{17}H_{18}ON_4S$. Calculated %: N 17.16.

2-Benzoyl-3-o-tolylthiazolidine. To 1.67 g (0.01 mole) of N-(β -mercaptoethyl)-o-toluidine in 3 ml of anhydrous alcohol was added 5.36 g (0.04 mole) of phenylglyoxal in 2 ml of anhydrous alcohol. The mixture, which evolved a little heat, was heated to boiling and poured into ice (50 g) with stirring. The yellow oil formed rapidly crystallized; the m. p. was 80.5-81° (from 80% alcohol). The yield was 2.24 g (79%).

Found %: C 72.42, 72.26; H 6.14, 6.10; N 4.83, 4.79. $C_{17}H_{17}ONS$. Calculated %: C 72.05; H 6.05; N 4.80.

2-Benzoyl-3-p-tolylthiazolidine. From 1.67 g of N-(β -mercaptoethyl)-p-toluidine and 5.36 g of phenylglyoxal, we obtained 2.70 g (95%) of ketone with m. p. 114.5-115° (from alcohol) by the method described in the previous experiment.

Found %: C 72.20, 72.19; H 6.22, 6.20; N 4.89, 4.77. $C_{17}H_{17}ONS$. Calculated %: C 72.05; H 6.05; N 4.80.

Semicarbazone with m. p. 223-224°.

Found %: N 16.74, 16.84. $C_{18}H_{20}ON_4S$. Calculated %: N 16.46.

2-Benzoyl-3-o-anisylthiazolidine. From 1.83 g of N-(β -mercaptoethyl)-o-anisidine and 5.36 g of phenylglyoxal we obtained 2.46 g (82%) of ketone with m. p. 99.5-100° (from alcohol) by the method described above.

Found %: C 67.97, 68.16; H 5.89, 5.79; N 4.78, 4.63. $C_{17}H_{17}O_2NS$. Calculated %: C 68.19; H 5.73; N 4.68.

2-Benzoyl-3-p-anisylthiazolidine. From 1.83 g of N-(β -mercaptoethyl)-p-anisidine and 5.36 g of phenylglyoxal we obtained 2.4 g (80%) of ketone with m. p. 141.5-142° (from alcohol).

Found %: C 68.04, 68.30; H 5.77, 5.82; N 4.85, 4.72. $C_{17}H_{17}O_2NS$. Calculated %: C 68.19; H 5.73; N 4.68.

Semicarbazone with m. p. 232-233°.

Found %: N 15.32, 15.41. $C_{18}H_{20}O_2N_4S$. Calculated %: N 15.72.

2-Benzoyl-3-p-carbethoxyphenylthiazolidine. A mixture of 1.12 g of N-(β -mercaptoethyl)-p-carbethoxyaniline in 2 ml of anhydrous alcohol and 2.68 g of phenylglyoxal in 1 ml of anhydrous alcohol was heated to boiling and poured into 50 ml of cold water. The liberated oil was separated and dissolved in 1 ml of anhydrous alcohol; on standing, crystals of ketone were deposited; the m. p. was 98-98.5° (from alcohol). The yield was 0.7 g (43%).

Found %: C 66.76, 66.99; H 5.76, 5.80; N 4.02, 4.24. $C_{19}H_{19}O_3NS$. Calculated %: C 66.84; H 5.61; N 4.10.

Semicarbazone with m. p. 236-237°.

Found %: N 13.84. $C_{20}H_{22}O_3N_4S$. Calculated %: N 14.06.

2-Acetyl-3-arylthiazolidines formed colorless crystals, which were readily soluble in alcohol, ether, benzene, acetone and dichloroethane and insoluble in water.

2-Benzoyl-3-arylthiazolidines formed yellow crystals (2-benzoyl-3-p-carbethoxyphenylthiazolidine was colorless), which were readily soluble in ether, benzene, acetone and dichloroethane, difficultly soluble in alcohol and insoluble in water.

2-Acyl-3-arylthiazolidines were quite stable to the action of alkalis; when they were boiled with 40% sodium hydroxide solution, a reaction for a sulfhydryl group appeared after 1-1.5 hours. Under the action of concentrated hydrochloric acid, a reaction for a sulfhydryl group appeared after 3-5 minutes.

SUMMARY

The reaction of N-(β -mercaptoethyl)-arylamines with α -ketoaldehydes (methyl- and phenylglyoxal) is a convenient method of preparing a previously undescribed type of ketone of the thiazolidine series, 2-acyl-3-arylthiazolidines.

LITERATURE CITED

- [1] Yu. K. Yur'ev and L. S. German, *J. Gen. Chem.* 26, 550 (1956).*
- [2] Yu. K. Yur'ev and S. V. Dyatlovitskaya, *J. Gen. Chem.*, 27, 1787 (1957).*
- [3] Yu. K. Yur'ev, S.V. Dyatlovitskaya and L. G. Bulavin, *J. Gen. Chem.*, 27, 3271 (1957).*
- [4] Yu. K. Yur'ev and S. V. Dyatlovitskaya, *J. Gen. Chem.* 28, 2377 (1958).*
- [5] S. V. Tsukerman, *Ukr. Chem. J.* 19, 523 (1953).
- [6] A. Cook and L. Helbronn, *Chemistry of Penicillin*, Princeton, New Jersey, 961 (1949).
- [7] L. Bellamy, *Infrared Spectra of Molecules*, Foreign. Lit. Press, 160 (1957) [Russian translation].
- [8] G. Gever, C. O'Keefe, G. Drake, F. Ebetino, J. Michels and K. Hayes, *J. Am. Chem. Soc.* 77, 2281 (1955).

Received February 20, 1958

* Original Russian pagination. See C.B. Translation.

CHEMISTRY OF SELENOPHENE

XVI. 4- and 5-NITROSELENOPHENE-2-ALDEHYDE AND THE SYNTHESIS OF ISOMERIC MONONITROSELENOPHENES

Yu. K. Yur'ev and E. L. Zaitseva

Moscow State University

In a previous paper of ours [1] it was reported that in an acetic anhydride medium selenophene-2-aldehyde was readily nitrated with fuming nitric acid (d 1.5), to which 5-7% sulfuric acid had been added, to give the diacetate of 5-nitroselenophene-2-aldehyde. Hydrolysis of the latter gave 5-nitroselenophene-2-aldehyde, oxidation of which with potassium bichromate in an acid medium led to 5-nitroselenophene-2-carboxylic acid.

In the present work we decarboxylated 5-nitroselenophene-2-carboxylic acid by Rinkes' method [2] in quinoline in the presence of reduced copper powder and obtained 2-nitroselenophene in 59.5% yield.

However, the 2-nitroselenophene that we obtained melted at 33.5-34° and thus differed from the preparation described by Umezawa [3] as the product of direct nitration of selenophene and which melted at 45-46°. Since neither recrystallization nor vacuum sublimation changed the melting point of the 2-nitroselenophene we obtained and elementary analysis data corresponded to a mononitroselenophene, we came to the conclusion that the preparation described by Umezawa was a mixture of 2- and 3-nitroselenophenes and that this problem could be solved by a study of the absorption spectra of the isomeric mononitroselenophenes obtained by different methods.

We plotted the ultraviolet absorption spectra of 2-nitroselenophene (m. p. 33.5-34°), obtained by decarboxylation of 5-nitroselenophene-2-carboxylic acid, a nitroselenophene preparation (m. p. 45-47°) obtained by nitration of selenophene by Umezawa's method [3] and also 3-nitroselenophene (m. p. 77.5-78°) obtained by decarboxylation of 4-nitroselenophene-2-carboxylic acid.

The absorption spectrum curves shown in Fig. 1 conclusively show that the nitroselenophene preparation, described by Umezawa as 2-nitroselenophene, was actually a mixture of mononitroselenophenes, 3-nitroselenophene (70%) and 2-nitroselenophene (30%).

An artificial mixture of 2- and 3-nitroselenophene of this composition, which we prepared, melted at 45-47° and its absorption curve corresponded with that of the nitroselenophene preparation obtained according to Umezawa's description.

Undoubtedly, the results we obtained explain why Umezawa [3] obtained 2,4-dinitroselenophene as the sole nitration product of the 2-nitroselenophene he described; the bulk of the "2-nitroselenophene", i. e., 3-nitroselenophene, formed 2,4-dinitroselenophene. To this we should add that in the thiophene series, nitration of 2-nitrothiophene under the same conditions yielded a mixture of 2,4- and 2,5-dinitrothiophenes [4].

Thus, for the preparation of 2-nitroselenophene in a pure form, it is necessary to start from 5-nitroselenophene-2-carboxylic acid since direct nitration of selenophene leads to a mixture of mononitroselenophenes.

In the present work 4-nitroselenophene-2-aldehyde was prepared by the nitration of selenophene-2-aldehyde with a nitrating mixture in the absence of acetic anhydride according to a procedure which should have given 4-nitrothiophene-2-aldehyde in 64.5% yield by nitration of thiophene-2-aldehyde [5].

However, in a later investigation by Gever [6], it was established that the 4-nitrothiophene-2-aldehyde obtained by Fove et al. [5] was actually a mixture containing 50% of 5-nitrothiophene-2-aldehyde and 50% of 4-nitrothiophene-2-aldehyde and by recrystallization of this from isopropyl alcohol he was able to isolate a small amount (12.5%) of 4-nitrothiophene-2-aldehyde in a pure form.

In a similar nitration of selenophene-2-aldehyde, we obtained a mixture of reaction products consisting of 4-nitroselenophene-2-aldehyde (45%), 5-nitroselenophene-2-aldehyde (5%) and 2,4-dinitroselenophene (50%).

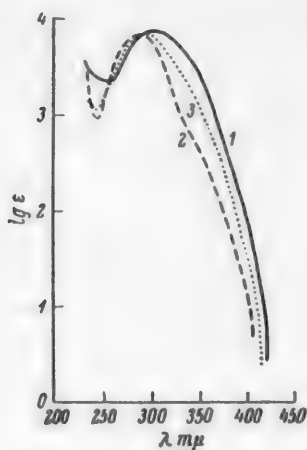


Fig. 1. Ultraviolet absorption spectra. 1) 2-nitroselenophene, 2) 3-nitroselenophene, 3) preparation of nitroselenophene obtained according to Umezawa's description.

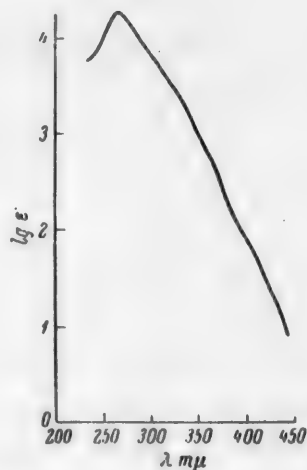
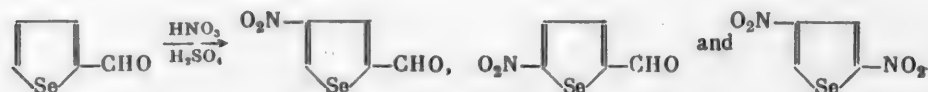
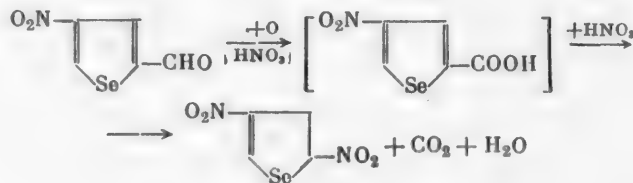


Fig. 2. Ultraviolet absorption spectrum of 2,4-dinitroselenophene.



By separating the semicarbazones of the nitroselenophenealdehydes, we isolated 2,4-dinitroselenophene in a yield of 37.5% (calculated on the selenophene-2-aldehyde used for the reaction); its ultraviolet absorption spectrum is shown in Fig. 2.

The formation of 2,4-dinitroselenophene must be by replacement by a nitro group of the carboxyl in 4-nitroselenophene-2-carboxylic acid, the oxidation product of the 4-nitroselenophene-2-aldehyde obtained.



Similar replacement of a carboxyl group by a nitro group is well known in the furan and thiophene series; in the nitration of pyromucic acid [7] with fuming nitric acid in an acetic anhydride medium, the main reaction product was 2-nitrofuran and in the nitration of 2-methylfuran-5-carboxylic acid, 2-methyl-5-nitrofuran;

in the nitration of thiophene-2-carboxylic acid under analogous conditions [2], 2-nitrothiophene was a side reaction product.

For determining the composition of the mixture of semicarbazones of nitroselenophenealdehydes obtained, we plotted the ultraviolet absorption spectra of pure preparations of the semicarbazone of 4-nitroselenophene-2-aldehyde (isolated from the mixture) and the semicarbazone of 5-nitroselenophene-2-aldehyde and also of the unrecrystallized mixture of these semicarbazones, precipitated for the separation from 2,4-dinitroselenophene, which was separated from it by solution in warm ether.

The absorption spectrum curves presented in Fig. 3 show that the unpurified mixture of semicarbazones contained 90% of the semicarbazone of 4-nitroselenophene-2-aldehyde and 10% of the semicarbazone of 5-nitroselenophene-2-aldehyde; the absorption curve of this mixture and artificial mixture of the semicarbazones with the same composition agreed.

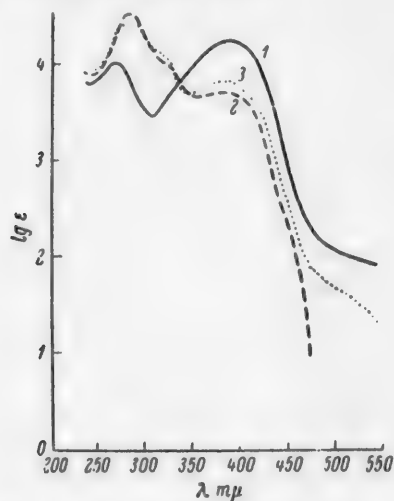


Fig. 3. Ultraviolet absorption spectra. 1) Semicarbazone of 5-nitroselenophene-2-aldehyde, 2) semicarbazone of 4-nitroselenophene-2-aldehyde, 3) unpurified mixture of semicarbazone obtained from the nitration product of selenophene-2-aldehyde with a nitrating mixture.

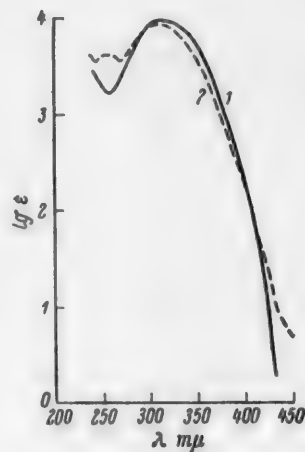
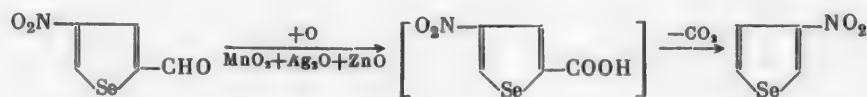


Fig. 4. Ultraviolet absorption spectra. 1)-5-nitroselenophene-2-aldehyde, 2) 4-nitroselenophene-2-aldehyde.

By isolating the semicarbazone of 4-nitroselenophene-2-aldehyde in a pure form and hydrolyzing it, we obtained 4-nitroselenophene-2-aldehyde and oxidation of this in a quinoline medium at an elevated temperature yielded 3-nitroselenophene as the decarboxylation product of the 4-nitroselenophene-2-carboxylic acid formed.



The constants of the 3-nitroselenophene obtained in this way agreed with the constants reported for it by Umezawa [8], who obtained 3-nitroselenophene by nitration of selenophene-2-sulfonyl chloride with subsequent hydrolysis of the 4-nitroselenophene-2-sulfonyl chloride formed.

The ultraviolet absorption spectra of 4- and 5-nitroselenophene-2-aldehyde are shown in Fig. 4.

Comparison of the ultraviolet absorption spectra of the α -nitro derivatives of selenophene with the absorption spectra of the α -nitro derivatives of furan [9] and thiophene [6,10] shows that they all have an intense absorption band in the region of 300 $m\mu$, that they are similar to each other in character and that the character of the spectra is caused by their diene structure, while the nature of the hetero atom does not have a substantial effect on it.

EXPERIMENTAL

2-Nitroselenophene. 1.1 g (0.005 mole) of 5-nitroselenophene-2-carboxylic acid [1] was mixed with 7 ml of quinoline and 0.45 g of reduced copper powder and slowly heated on an oil bath to 215° (thermometer in liquid). Carbon dioxide was evolved vigorously at 150–180°. To the cooled mixture was added 30 ml of dilute hydrochloric acid (1:1) and the 2-nitroselenophene steam distilled and collected by filtration. We obtained 0.35 g (40%) and a further 0.17 g (19.5%) from ether extracts of the aqueous part of the distillate; the yellow crystals had m. p. 33.5–34° (from petroleum ether).

Found %: C 27.53, 27.39; H 1.90, 1.97; Se 44.71, 44.73. $C_4H_3O_2NSe$. Calculated %: C 27.29; H 1.72; Se 44.85.

When 4.6 g (0.035 mole) of selenophene in 13 ml of acetic anhydride was nitrated with 2 ml of fuming nitric acid (d = 1.5) in 20 ml of glacial acetic acid by Umezawa's method [3], we obtained 0.9 g (11%) of a yellow crystalline mass; m. p. 45–47° (from petroleum ether).

Found %: C 27.52, 27.37; H 2.20, 2.04. $C_4H_3O_2NSe$. Calculated %: C 27.29; H 1.72.

Literature data; m. p. 45–46° [3].

Mixture of 4- and 5-nitroselenophene-2-aldehydes. With stirring, 15.9 g (0.1 mole) of selenophene-2-aldehyde was slowly added to 14 ml of concentrated sulfuric acid at –15°. Then a nitrating mixture consisting of 23.7 g (0.36 mole) of fuming nitric acid (d 1.5) and 9.75 ml of concentrated sulfuric acid (d 1.84) and first cooled to 0° was added at such a rate that the temperature did not rise above –20°. The mixture was stirred for a further 2 hours at –20°, then gradually heated up to 0° over a period of 30 minutes and poured into ice (350 g). The precipitate was collected and washed with cold water. We obtained 18.35 g of light-yellow crystals with m. p. 37–41°, which were a mixture of 4- and 5-nitroselenophene-2-aldehydes and 2,4-dinitroselenophene.

Semicarbazone of 4-nitroselenophene-2-aldehyde. 10 g of crystals with m. p. 37–41°, 5.6 g of semicarbazide hydrochloride and 200 ml of water were heated together for 5 minutes on a boiling water bath. The precipitate was collected, washed with water and dried. We obtained 10.5 g of yellow crystals, melting at 203–205° (with decomp.). Careful treatment of these with warm ether and filtration yielded 6 g (42%, calculated on the aldehyde used for the reaction) of a mixture of the semicarbazones of 4- and 5-nitroselenophene-2-aldehyde with m. p. 226–227° (with decomp.). Recrystallization from nitrobenzene and then alcohol yielded 3.6 g (25.5%, calculated on the selenophene-2-aldehyde introduced into the reaction) of the semicarbazone of 4-nitroselenophene-2-aldehyde as yellow crystals with m. p. 236–238° (with decomp.).

Found %: C 27.95, 27.99; H 2.53, 2.63; Se 29.75, 29.78. $C_4H_3O_2N_4Se$. Calculated %: C 27.59; H 2.32; Se 30.12.

2,4-Dinitroselenophene. The aqueous filtrate from the mixture of semicarbazones obtained was extracted with ether and these extracts were combined with the ether solution obtained by treatment of the mixture of semicarbazones with ether, dried with anhydrous sodium sulfate and the ether removed. The residue (5 g) was recrystallized from petroleum ether. We obtained 4.5 g (37.5%, calculated on the selenophene-2-aldehyde introduced into the reaction) of 2,4-dinitroselenophene as long yellow needles with m. p. 78.5–79°.

Found %: C 21.53, 21.68; H 1.12, 1.16. $C_4H_2O_4N_2Se$. Calculated %: C 21.28; H 0.91.

Literature data; m. p. 78–79° [3].

4-Nitroselenophene-2-aldehyde. 3 g of the semicarbazone of 4-nitroselenophene-2-aldehyde and 80 ml of 50% sulfuric acid were boiled together for 3 hours under reflux and the aldehyde steam distilled with the acid concentration kept at 50–60% by the continuous addition of an appropriate amount of water. The distillate was cooled with ice; the crystals were separated (0.46 g), the filtrate extracted with ether and the ether evaporated to yield a further small amount of crystals (0.27 g).

We obtained 0.73 g (31.0%) of aldehyde as pale-yellow needles with m. p. 69–69.5° (from petroleum ether).

Found %: C 29.38, 29.51; H 1.44, 1.56; Se 38.62, 38.44. $C_4H_3O_2NSe$. Calculated %: C 29.38; H 1.48; Se 38.70.

The thiosemicarbazone of 4-nitroselenophene-2-aldehyde was obtained by heating 1 g of the unpurified product from nitration of selenophene-2-aldehyde and 0.45 g of the thiosemicarbazide in 15 ml of alcohol with 10 drops of glacial acetic acid and subsequently adding 16 ml of water. After the precipitate had been washed with warm ether and repeatedly recrystallized from nitrobenzene and then from 50% ethyl alcohol, we obtained 0.3 g of orange crystals with m. p. 242-243° (with decomp.).

The thiosemicarbazone obtained from pure 4-nitroselenophene-2-aldehyde also melted at 242-243° (with decomp.) and a mixed melting point with the previous preparation was not depressed.

Found % C 26.43, 26.24; H 2.44, 2.43. $C_6H_4O_2N_4SSe$. Calculated % C 26.00; H 2.18.

3-Nitroselenophene. 0.51 g (0.0025 mole) of 4-nitroselenophene-2-aldehyde was mixed with 1.2 g of an equal weight mixture of MnO_2 , Ag_2O and ZnO in 3 ml of quinoline and slowly heated on an oil bath to 230°. Vigorous evolution of carbon dioxide occurred at 120-160°. To the cooled mixture was added 10 ml of dilute hydrochloric acid (1:1) and the 3-nitroselenophene steam distilled. The distillate was extracted with ether and the ether extracts dried with anhydrous sodium sulfate. Removal of the ether left a yellow oil, which rapidly crystallized. We obtained 0.11 g (25%) of 3-nitroselenophene as long, colorless needles with m. p. 77.5-78° (from petroleum ether and subliming in vacuum at 12 mm and 100-110°).

Found % C 27.15, 27.24; H 1.72, 1.82. $C_4H_3O_2NSe$. Calculated % C 27.29; H 1.72.

Literature data; m. p. 77-78.5° [8].

Data from the measurements are presented in the table.

Name of compound	Absorption maximum		Name of compound	Absorption maximum	
	m μ	ϵ_a		m μ	ϵ_a
Nitroselenophenes			Semicarbazones of nitroselenophene-2-aldehyde		
2-Nitroselenophene	200	7480	Semicarbazone of 4-nitroselenophene-2-aldehyde	285.385	33350.5200
3-Nitroselenophene	290	6770			
Nitroselenophene preparation obtained by Umezawa's method; m. p. 45-47°	295	7245	Semicarbazone of 5-nitroselenophene-2-aldehyde	266.385	10100.18000°
Artificial mixture of 30% 2-nitroselenophene and 70% 3-nitroselenophene; m. p. 45-47°	294	7262	Unpurified mixture of semicarbazones obtained from the nitration product of selenophene-2-aldehyde with nitrating mixture	285.385	29520.6790
2,4-Dinitroselenophene	268	18000	Artificial mixture of the semicarbazones of 5-nitroselenophene-2-aldehyde (10%) and 4-nitroselenophene-2-aldehyde (90%)	286.384	29720.6680
Nitroselenophene-2-aldehydes					
4-Nitroselenophene-2-aldehyde	260, 309	4100, 8810			
5-Nitroselenophene-2-aldehyde	310	9290			

The ultraviolet absorption spectra of selenophene nitro derivatives were plotted on an SF-4 spectrophotometer with nonautomatic recording, using quartz cells and a hydrogen lamp. Methanol was the solvent used and the concentration was 10^{-4} M.

SUMMARY

1. Decarboxylation of 5-nitroselenophene-2-carboxylic acid led to the formation of pure 2-nitroselenophene. A preparation described previously in the literature and obtained by nitration of selenophene actually consisted of a mixture of 2-nitroselenophene (30%) and 3-nitroselenophene (70%).

2. Nitration of selenophene-2-aldehyde with a nitration mixture yielded a mixture of reaction products consisting of 4-nitroselenophene-2-aldehyde, 5-nitroselenophene-2-aldehyde and 2,4-dinitroselenophene. 4-Nitroselenophene-2-aldehyde and 2,4-dinitroselenophene were isolated from this mixture. The presence of 5-nitroselenophene-2-aldehyde in it was demonstrated by the ultraviolet absorption spectrum.

3. Oxidation of 4-nitroselenophene-2-aldehyde and decarboxylation of the 4-nitroselenophene-2-carboxylic acid formed led to the formation of 3-nitroselenophene.

4. The ultraviolet absorption spectra of the selenophene nitro derivatives studied were analogous to the spectra of the corresponding nitro derivatives of the furan and thiophene series, since their character is due to the diene structure of these compounds and not the nature of the hetero atom.

LITERATURE CITED

- [1] Yu. K. Yur'ev and E. L. Zaitseva, *J. Gen. Chem.* 28, 2164 (1958).*
- [2] I. J. Rinkes, *Rec. trav. chim.* [4], 51, 1134 (1932).
- [3] S. Umezawa, *Bull. Chem. Soc. Japan*, 11, 775 (1936).
- [4] W. Steinkopf and T. Hopner, *Lieb. Ann.* 501, 174 (1933).
- [5] W. O. Fove, J. J. Hefferren and E. L. Feldman, *J. Am. Chem. Soc.* 76, 1378 (1954).
- [6] G. Gever, *J. Am. Chem. Soc.* 77, 577 (1955).
- [7] I. J. Rinkes, *Rec. trav. chim.*, [4], 49, 1118, 1169 (1930).
- [8] S. Umezawa, *Bull. Chem. Soc. Japan*, 12, 4 (1937).
- [9] S. A. Giller and N. O. Saldabols, *Bull. Acad. Sci. USSR, Div. Phys. Sci.*, 17, 708 (1953).
- [10] F. S. Boig, G. W. Costa and L. Osvar, *J. Org. Ch.*, 18, 774 (1953).

Received March 12, 1958.

*Original Russian pagination. See C.B. Translation.

HYDROGENATION OF FURAN COMPOUNDS ON PLATINUM AND RHODIUM CATALYSTS

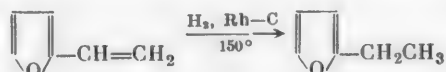
N. I. Shuikin and I. F. Bel'skii

Institute of Organic Chemistry, Academy of Sciences, USSR

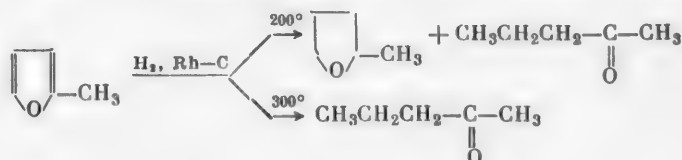
The results of hydrogenation of furan compounds in the presence of catalysts containing metals of group VIII of the periodic system leads to the conclusion that certain of these metals are more effective in the hydrogenation of the double bonds of the furan ring and others show a high activity in hydrogenolysis of the ether bonds of the furan ring. Thus, in the vapor phase at temperatures of 80 and 140°, respectively, osmium [1] and palladium [2] catalysts hydrogenate the furan ring into tetrahydrofuran without any side reactions. A rise in reaction temperature generally promotes hydrogenolysis of the ring to a lesser extent on palladium and to a greater extent on nickel catalysts. Even at 275° palladized charcoal mainly hydrogenates the double bonds of the furan ring and, consequently, has the greatest specificity as regards this reaction [3]. On the other hand, in the hydrogenation of furan homologs at 275°, platinized charcoal promotes only hydrogenolysis of the ring at the 1-5 C-O bond with the formation of aliphatic ketones [4]. Nickel catalysts show very different properties, depending on the nature of the carrier. At temperatures of not more than 140-150° in the vapor phase, skeletal Ni-Al catalyst predominantly hydrogenates the furan ring, while at 235-275°, only the so-called "conjugated" hydrogenolysis of the furan ring occurs [5]. In the vapor phase at 140°, nickel on zinc oxide selectively hydrogenates olefin bonds in the side chain and does not show any noticeable activity as regards hydrogenation of the double bonds of the furan ring. At 250° nickel on zinc oxide behaves similarly to platinized charcoal [6]. However, if a hydrogenation is performed over this catalyst in the liquid phase at 200-250°, then together with hydrogenolysis of the furan ring at the 1-5 C-O bond, there is also hydrogenation of the double bonds in the ring with the formation of the corresponding tetrahydro derivative [7].

The data presented above show that in the general case, comparative data on the properties of catalysts may only be obtained by carrying out reactions under definite "standard" conditions. Starting from these premises, in the present work we investigated the hydrogenation of sylvan and α -vinylfuran on rhodium deposited on activated charcoal, in the vapor phase at 150, 200 and 300°. To obtain comparative data, we also hydrogenated sylvan and α -propenylfuran over platinized charcoal in the vapor phase at 150°.

The furan ring was hydrogenated extremely slowly over a rhodium catalyst at 150°, which makes it possible to reduce an olefin bond in the side chain with the retention of the double bonds in the ring. At this temperature, α -vinylfuran was converted into α -ethylfuran in yields of up to 90%:



Hydrogenation of sylvan on Rh-C at 200° led to the formation of a mixture of tetrahydrosylvan (40%) and pentanone-2 (60%); at 300°, the hydrogenation products of sylvan contained only pentanone-2.



A similar picture was observed in the hydrogenation of sylvan and α -propenylfuran over Pt-C at 150°. The olefin bond in the side chain was reduced much more rapidly than the double bonds in the furan ring were hydrogenated and due to this, α -propenylfuran was converted into α -propylfuran in yields of 90-95%. When passed over Pt-C at 150° 3 times in succession at a volume rate of 0.1 hour⁻¹, sylvan remained 70% unchanged. The reaction products contained tetrahydrosylvan (26%), pentanone-2 (59%) and pentanol-2 (15%). Thus, even at a relatively low temperature, platinized charcoal predominantly promotes hydrogenolysis of the furan ring. If these results are compared with the experimental data which we obtained previously [3] in the hydrogenation of sylvan in the vapor phase on Pt-C and Pd-C at 275°, we may arrive at the following conclusions.

1. In vapor-phase hydrogenation over a wide temperature range (140-275°), palladized charcoal is a specific catalyst for hydrogenation of the double bonds in the furan ring.
2. Under similar conditions, platinized charcoal is a specific catalyst for hydrogenolysis of the furan ring at the 1-5 C-O bond.

Since the rate of hydrogenolysis of the furan ring increases with an increase in temperature, then apparently the lower limit of the given temperature range is most advantageous for the selective action of palladized charcoal, while complete hydrogenolysis of the furan ring on Pt-C occurs at temperatures above 250°.

3. At 300° Rh-C behaves completely analogously to platinized charcoal, while at a lower temperature (200°), according to its properties, it occupies an intermediate position between Pd-C and Pt-C, since it promotes hydrogenation of the double bonds in the furan ring less than the former and more than the latter.

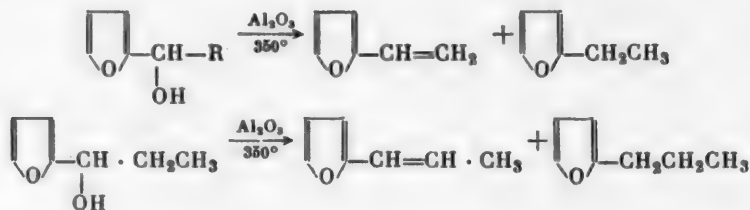
EXPERIMENTAL

Catalysts. Finely dispersed rhodium on charcoal, containing 5% Rh, was prepared by impregnating activated birchwood charcoal with a solution of rhodium trichloride and subsequently reducing with hydrogen in a reaction tube at 250-300°. The preparation of 15% platinized charcoal was described in one of our previous papers [4].

Starting materials. The sylvan used for the experiments was isolated from the technical preparation by distillation on a column with an efficiency of 40 theoretical plates.

B. p. 63-64° (752), d_4^{20} 0.9120, n_D^{20} 1.4320.

α -Vinyl- and α -propenylfurans were obtained by dehydration of the corresponding methyl- and ethyl-furylcarbinols over aluminum oxide at 350°. Here, α -ethyl- and α -propylfurans were also obtained in a smaller amount.



α -Vinyl- and α -propenylfurans, isolated from the dehydration products by distillation on an efficient column, had the following properties.

α -Vinylfuran, b. p. 98-99.5° (755), d_4^{20} 0.9487, n_D^{20} 1.5010.

α -Propenylfuran, b. p. 132-133° (752), d_4^{20} 0.9457, n_D^{20} 1.5098.

Experimental conditions. Sylvan and α -vinyl- and α -propenylfurans were hydrogenated over Pt-C and Rh-C in the vapor phase at various temperatures. In each case 30 g of material was used and passed at a volume rate of 0.1 hour⁻¹. The catalyzates obtained were dried with calcium chloride and distilled on a column with an efficiency of 40 theoretical plates.

Data on the experimental conditions and the yields of reaction products as percent of material converted are given in the table.

Catalytic Hydrogenation of Sylvan and α -Vinyl- and α -Propenyl-furans

Starting material	Catalysts	Reaction temperature	Hydrogenation product
Sylvan	Pt-C	150	Tetrahydrosylvan (26%) Pentanone-2 (59%) , pentanol-2 (15%)
Sylvan	Rh-C	200	Tetrahydrosylvan (40%) Pentanone-2 (60%)
Sylvan	Rh-C	300	Pentanone-2 (~100%)
α -Vinylfuran	Rh-C	150	α -Ethylfuran (90%)
α -Propenylfuran	Pt-C	150	α -Propylfuran (90-95%)

SUMMARY

1. In the hydrogenation of α -alkenylfurans on Pt-C and Rh-C in the vapor phase at 150°, reduction of the olefin bond in the side chain occurs with the result that the corresponding α -alkylfurans are formed in 90-95% yield.
2. On Pt-C at 150°, the furan ring reacts with hydrogen extremely slowly, undergoing hydrogenolysis at the double bonds (20-25%) on the one hand and hydrogenolysis at the 1-5 C-O bond (75-80%) on the other.
3. On Rh-C at 200°, the furan ring undergoes hydrogenation into tetrahydrofuran (40%) and hydrogenolysis at the 1-5 C-O bond with the formation of the corresponding ketone (60%); at 300° on Rh-C, there is only hydrogenolysis of the furan ring.

LITERATURE CITED

- [1] N. D. Zelinskii and N. I. Shuikin, Proc. Acad. Sci. USSR, 60 (1933); N. I. Shuikin and E. M. Chilikina, J. Gen. Chem. 6, 279 (1936).
- [2] N. I. Shuikin et al., J. Gen. Chem., 7, 1501 (1937); J. Gen. Chem., 8, 669, 674 (1938).
- [3] N. I. Shuikin and I. F. Bel'skii, Proc. Acad. Sci. USSR, 115, 330 (1957).*
- [4] N. I. Shuikin and I. F. Bel'skii, Proc. Acad. Sci. USSR, 116, 621 (1957).*
- [5] N. Chouikine and L. Belski, Bull. Soc. Chim, 1956, 1556.
- [6] N. I. Shuikin and I. F. Bel'skii, J. Gen. Chem., 29, 442 (1959).*
- [7] N. I. Shuikin and I. F. Bel'skii, J. Gen. Chem., 29, No. 3 (1959).*

Received March 6, 1958

*Original Russian pagination. See C.B. Translation.

CATALYTIC REDUCTION OF 2-METHYL-5-ACETYLFURAN TO 2-METHYL-5-ETHYLFURAN

N. I. Shuikin and I. F. Bel'skii

Institute of Organic Chemistry, Academy of Sciences, USSR

The hydrogenation of ketones of the furan series has been the subject of many investigations. From the point of view of studying the possibility of selective hydrogenation, furfurylidene ketones, obtained by the condensation of furfural with an active methylene group, are very convenient materials since they contain at least three types of unsaturated bonds, olefin, carbonyl and the double bonds in the furan ring. Ketones of this type have been hydrogenated in the liquid phase in the presence of various catalysts (Ni, Pt, Pd and Cu).

The experimental results obtained lead to certain general conclusions on the sequence of hydrogenation of unsaturated bonds in relation to the nature of the catalyst and the temperature. A whole series of papers show that over a nickel catalyst, hydrogenation of the olefin bond occurs first, then of the carbonyl group and finally of the double bonds in the furan ring. These experimental results are in good agreement with the conclusions of the multiplet theory [1].

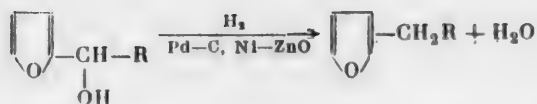
However, it should be noted that the capacity of a catalyst for performing any particular reaction selectively is substantially affected by the phase in which the reaction is performed. Thus, for example, skeletal Ni-Al has a high activity in hydrogenation of the furan ring in the liquid and in the vapor phase, while nickel on zinc oxide will only hydrogenate the furan ring in the liquid phase [2].

Selective reduction of the olefin bond on nickel catalysts (Raney nickel and nickel on kieselguhr) is possible at temperatures no higher than 50-70°. At higher temperatures the carbonyl group of furan ring are also hydrogenated and as a result alcohols of the tetrahydrofuran series are formed [3]. Selective hydrogenation of the carbonyl group with retention of the double bonds in the furan ring is readily accomplished in the presence of copper chromite at 90-175° [3].

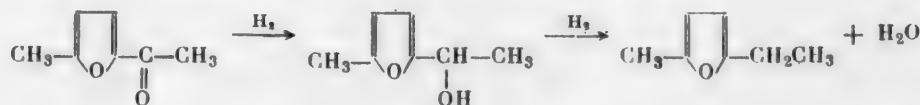
A platinum catalyst has interesting properties in the hydrogenation of ketones and aldehydes of the furan series. Bray and Adams [4] found that in the reduction of furalacrolein on platinum, promoted by iron and zinc salts, the carbonyl group was first hydrogenated, then the olefin bond and after that, the furan ring. Similarly, in the hydrogenation of furfural on a platinum catalyst, Adams first reduced the carbonyl group and then the furan ring [5]. However, the reduction of unsaturated bonds in ketones (furalacetophenone) under the same conditions proceeds in another sequence, namely, the olefin bond, the furan ring and the carbonyl group [5]. Thus, the relative ease of reduction of the olefin bond, the carbonyl group and the furan ring depends not only on the nature of the catalyst, but also on the chemical structure of the compound. Palladium catalysts have been investigated very little in the hydrogenation of ketones of the furan series. Alder and Schmidt [6] found that in the presence of palladium at 25°, only the olefin bond was hydrogenated in the molecules of 5-methylfurfurylideneacetone and 5-methylfurfurylideneacetophenone, while the carbonyl group and the furan ring remained untouched.

In the present work we investigated the hydrogenation of 2-methyl-5-acetylfuran in the vapor phase at 250° over Ni-ZnO, Ni-CdO and Pd-C.

As we showed previously [7], in the hydrogenation of alkylfurylcarbinols in the vapor phase on Pd-C and Ni-ZnO, the primary reaction is the reduction of the hydroxyl group to form the corresponding alkylfurans.

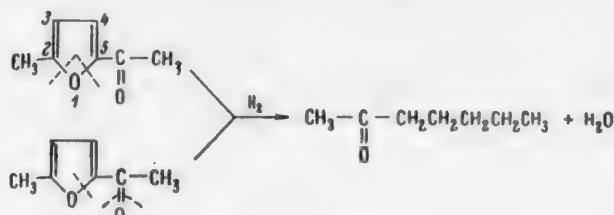


It was to be expected that in the hydrogenation of 2-methyl-5-acetylfuran, the methyl-(5-methylfuryl)-carbinol formed would undergo further reduction into 2-methyl-5-ethylfuran.



Actually, our experiments showed that 2-methyl-5-ethylfuran was formed in 55-60% yield in the hydrogenation of 2-methyl-5-acetylfuran in the vapor phase over Ni-ZnO and Ni-CdO at 250°. Under these conditions, palladized charcoal was almost completely indifferent both as regards reduction of the carbonyl group and hydrogenation of the furan ring in 2-methyl-5-acetylfuran. After this ketone had been passed over Pd-C at 250° 3 times, its conversion into 2-methyl-5-ethylfuran was not more than 5%.

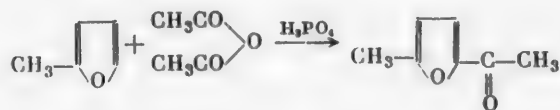
In the hydrogenation of 2-methyl-5-acetylfuran over Ni-ZnO, hydrogenolysis of the furan ring with the formation of heptanone-2 was a side reaction; this reaction hardly occurred over Ni-CdO. Heptanone-2 could be obtained either as a result of reductive elimination of the oxygen atom from the furan ring or as a result of complete reduction of the carbonyl group with simultaneous hydrogenolysis of the ring at the 1-5 C-O bond:



A final solution of this problem requires additional investigation. The direct catalytic reduction of alkyl furyl ketones into alkylfurans may have preparative value since it is a shorter and more convenient method than converting them into hydrazones and decomposing the latter by the Kizhner reaction [8].

EXPERIMENTAL

2-Methyl-5-acetylfuran was obtained by acetylation of sylvan with acetic anhydride in the presence of orthophosphoric acid.



The acetylation was performed in a flask fitted with a stirrer and a reflux condenser. To a mixture of 2 mole of sylvan and 3 mole of acetic anhydride, cooled to 0°, was added 10-15 g of orthophosphoric acid and the reaction mixture stirred at this temperature for 30 minutes and then heated for a further 3 hours on a water bath. After the reaction, the acetylation product was washed to a neutral reaction with sodium carbonate solution, extracted with ether and after removal of the latter, distilled under reduced pressure. The average yield of 2-methyl-5-acetylfuran with b. p. 68-69° (7 mm), d_{20}^{20} 1.0655 and n_D^{20} 1.5090 was 50%.

It is interesting to note that acetylation of the furan ring with acetic anhydride in the presence of iodine or hydriodic acid, which gives high yields of the monoacetyl derivative in the case of furan [9], was quite unsuitable for the preparation of α -acetylsylvan; in this case the bulk of the reaction products was a fraction with b. p. 149-154° (7 mm), which darkened in air quite rapidly.

Catalysts. Nickel on zinc oxide containing 30% of finely dispersed nickel was obtained by precipitation of nickel and zinc hydroxides from a solution of their nitrates with ammonia. The precipitate was washed free from nitrate ion (reaction with diphenylamine), filtered off, dried at 120° and formed into small cylinders. Into a reaction tube was placed 100 ml of catalyst, which was reduced with hydrogen at a gradually increasing temperature from 200 to 300° over a period of 10-12 hours.

The conditions for preparation of nickel on cadmium oxide (30% Ni) differed from those described above only in that the hydroxides of nickel and cadmium were precipitated not with ammonia, but with potassium hydroxide solution.

Palladium on charcoal, containing 10% Pd, was prepared by impregnating activated charcoal with palladium chloride solution and reducing the latter with formalin in the presence of potassium hydroxide at 0°.

Reaction conditions. 2-Methyl-5-acetylfuran was reduced by a flow method at 250°. The input volume rate for the substance was 0.1 hour⁻¹. After separation from water and drying with calcium chloride, the catalyzates were distilled on a column with an efficiency of 40 theoretical plates. The catalyzates obtained by the hydrogenation of 2-methyl-5-acetylfuran on Ni-ZnO and Ni-CdO gave a 55-60% yield of 2-methyl-5-ethylfuran with b. p. 117.8-118° (750 mm), d₄²⁰ 0.8930 and n_D²⁰ 1.4455.

A fraction with b. p. 145.5-150° (750 mm) gave a semicarbazone with m. p. 119-120° and consequently was heptanone-2. About 18% of this ketone was obtained over Ni-ZnO catalyst and a considerably smaller amount over Ni-CdO. The high-boiling part of the catalyzates (b. p. 52-95° at 7 mm, n_D²⁰ 1.4910-1.5125) was not examined, but evidently contained a certain amount of unconverted 2-methyl-5-acetylfuran.

SUMMARY

1. In the reduction of 2-methyl-5-acetylfuran on Ni-ZnO and Ni-CdO in the vapor phase at 250°, 2-methyl-5-ethylfuran was formed in 55-60% yield.

2. Under the same conditions 2-methyl-5-acetylfuran remained practically unchanged over palladized charcoal.

LITERATURE CITED

- [1] A. A. Balandin and A. A. Ponomarev, J. Gen. Chem. 26, 1146 (1956).*
- [2] N. I. Shuikin and I. F. Bel'skii, J. Gen. Chem. 29, 1086 (1959).*
- [3] H. Burdick and H. Adkins, J. Am. Chem. Soc. 56, 438 (1954); K. Alexander and G. Smith, J. Am. Chem. Soc., 71, 735 (1949).
- [4] R. Bray and R. Adams, J. Am. Chem. Soc. 49, 2101 (1927).
- [5] W. Kaufmann and R. Adams, J. Am. Chem. Soc. 45, 3029 (1923).
- [6] K. Alder and C. Schmidt, Ber. 76, 183 (1943).
- [7] N. I. Shuikin and I. F. Bel'skii, Proc. Acad. Sci. USSR, 117, 95 (1957)*; Bull. Acad. Sci. USSR, Div. Chem. Sci. 1958, 506.*
- [8] N. I. Shuikin, I. F. Bel'skii and Tyan' Sin-Khua, Proc. Acad. Sci. USSR, 116, 808 (1957).
- [9] H. Hartough and A. Kozak, J. Am. Chem. Soc. 68, 2639 (1946).

Received March 6, 1958

*Original Russian pagination. See C.B. Translation.

INVESTIGATION OF PYRAZOLES

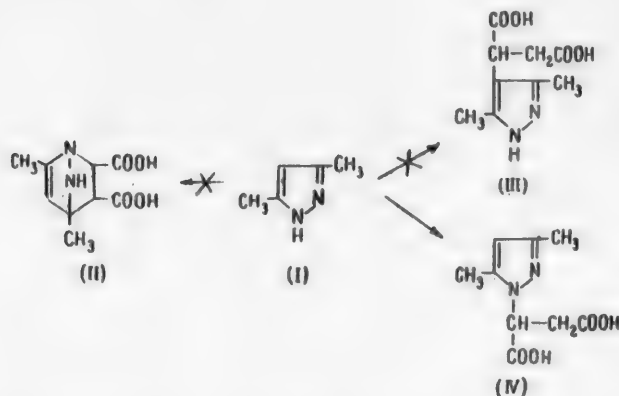
III. ADDITION OF α, β -UNSATURATED COMPOUNDS TO PYRAZOLES

I. I. Grandberg and A. N. Kost

Moscow State University

A communication by G. Ya. Kondrat'eva [1] recently appeared in which it was reported that oxazoles undergo the Diels-Alder reaction like dienes. We attempted to extend this reaction to pyrazoles. It was found that at 90-100° in dioxane, 3,5-dimethylpyrazole (I) reacted exothermically to add 1 molecule of maleic anhydride in a quantitative yield. 3,5-Dimethylpyrazole reacted almost as vigorously (but with lower yield) with *p*-benzoquinone, acrylonitrile and α -naphthoquinone. Methyl methacrylate reacted with 3,5-dimethylpyrazole much more sluggishly; an addition product was only obtained after heating the components for 3 hours at 200° in an autoclave. Even under these conditions, benzalacetone did not react and was recovered unchanged. As regards the pyrazole component, 3-methyl-5-phenyl- and 3,5-diphenylpyrazoles reacted with maleic anhydride analogously to 3,5-dimethylpyrazole, though under more drastic conditions (30 minutes, 170-180°).

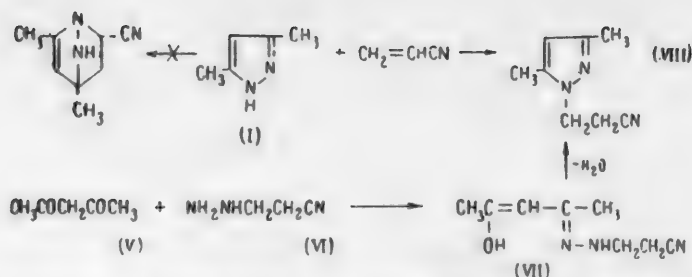
After opening of the anhydride ring with water, the compound obtained from 3,5-dimethylpyrazole and maleic anhydride behaved as a dibasic acid and consequently was either the product of diene synthesis (II) or was obtained due to the reaction of the labile hydrogen atoms in the pyrazole nucleus (III) or in the NH group (IV).



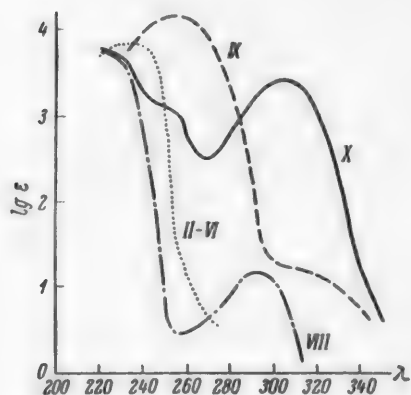
Variation (III) could be eliminated immediately since pyrazoles substituted in position 4 (3,4,5-trimethylpyrazole and 3,5-dimethyl-4-bromopyrazole) underwent the reaction with exactly the same ease.

For proof of whether the substance obtained had structure (II) or (IV), the following cycle of reactions was carried out.

The reaction of acetylacetone (V) with monocyanoethylated hydrazine (VI) yielded the monohydrazone (VIII), which was cyclized into *N*-cyanoethylated 3,5-dimethylpyrazole (VIII), which was completely identical with the substance obtained by the action of acrylonitrile on 3,5-dimethylpyrazole (I).



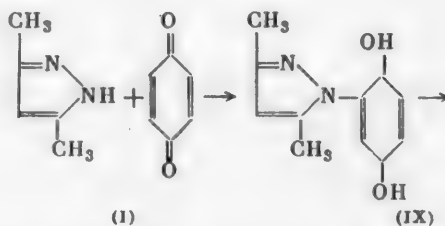
Thus, although pyrazole possesses an NH group with weakly acidic properties, it adds acrylonitrile without alkaline catalysts, which is not quite normal for the cyanoethylation reaction. The reaction with maleic anhydride apparently proceeds by an analogous scheme. The same type of reaction was observed by Wiley et al. [2], who added compounds with an activated double bond to triazole, tetrazole and 4-nitropyrazole under the action of Triton B or at high temperatures. We were unable to perform a diene synthesis, even under drastic conditions (110°, 20 hours), with 2,4-dimethylthiazole and acrolein, acrylonitrile and maleic anhydride, with 3,5-dimethylisoxazole and maleic anhydride (150°, 5 hours) or with N-methylimidazole and acrylonitrile (100°, 5 hours). In all cases, the heterocycles were recovered unchanged. 1,3,5-Trimethylpyrazole and 1-phenylpyrazole remained unchanged when heated with maleic anhydride for 10 hours at 160-180°.



Absorption spectra. The numbers of the curves correspond to the numbers of names of the compounds in the table.

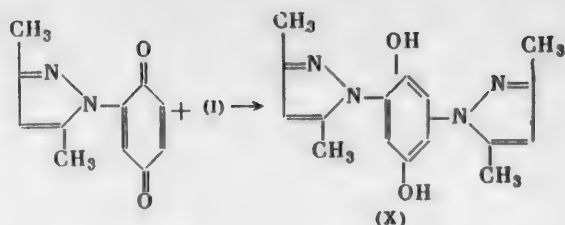
The reaction is somewhat more complicated in the case of quinone. Apparently the addition product (IX) first formed is oxidized by a second molecule of quinone and then adds a second molecule of pyrazole, forming 2,5-di-(3,5-dimethylpyrazolyl-1)-hydroquinone (X).

We plotted the ultraviolet absorption spectra of the whole series of compounds obtained.* It was found that replacement of the hydrogen atom of the NH group in 3,5-dimethylpyrazole by a grouping which did not have its own characteristic maximum did not change the character of the spectral curve of the original pyrazole [3] and did not even displace the maximum (see table). In the case of 3,5-dimethyl-1-(2'-cyanoethyl)-pyrazole (IV), an additional maximum appeared, evidently due to the cyano group. In exactly the same way, the spectra of the basic compounds (VII and XI) were completely identical with their derivatives (IX) and (XII). 2,5-Di-(3,5-dimethylpyrazolyl-1)-hydroquinone (X) had a weakly expressed maximum at about 220 mμ, characteristic of 3,5-dimethylpyrazole (I); the general form of the curve was characteristic of hydroquinone. The spectral curves are illustrated in the figure.



*The absorption spectra were plotted on an SF-4 spectrophotometer. The solvent used was methanol in all cases.

(continued)



No. of substance	Name of substance	λ_{\max} m μ	lg ϵ
(I)	3,5-Dimethylpyrazole	~ 220	~ 3.6
(IV)	3,5-Dimethylpyrazolyl-1-succinic acid	~ 220	~ 3.7
(VIII)	3,5-Dimethyl-1-(2'-cyanoethyl)-pyrazole	$\sim 220, 294$	$\sim 3.7, 4.17$
(II)	3,4,5-Trimethylpyrazolyl-1-succinic acid	232	3.79
(III)	3,5-Dimethyl-4-bromopyrazolyl-1-succinic acid	232	3.68
(V)	α -(3,5-dimethylpyrazolyl)- α -bromosuccinic acid	232	3.73
(VI)	Methyl ester α -methyl- β -(3,5-dimethylpyrazolyl-1)-propionic acid	~ 220	~ 3.7
(VII)	3-Methyl-5-phenylpyrazole	251	4.285
(IX)	3-Methyl-5-phenylpyrazolyl-1-succinic acid	254	4.150
(XI)	3,5-Diphenylpyrazole	254	4.564
(XII)	3,5-Diphenylpyrazolyl-1-succinic acid	252	4.56
(X)	2,5-Di-(3,5-dimethylpyrazolyl-1)-hydroquinone	$\sim 220, 306$	$\sim 3.7, 3.421$

EXPERIMENTAL

3,5-Dimethylpyrazolyl-1-succinic acid. A solution of 19.2 g of 3,5-dimethylpyrazole and 19.8 g of maleic anhydride in a mixture of 10 ml of octane and 50 ml of benzene was boiled for 3 hours on a water bath. The precipitate was recrystallized from 450 ml of water with the addition of 3 g of activated charcoal. We obtained 38.4 g (93%) of 3,5-dimethylpyrazolyl-1-succinic acid with m. p. 199-200° (in a sealed capillary).

Found %: C 51.26, 51.13; H 5.85, 5.79; N 13.17, 13.14. $C_9H_{12}O_4N_2$. Calculated %: C 59.94; H 5.71; N 13.21.

Titration of 3,5-dimethylpyrazolyl-1-succinic acid in an aqueous methanol solution with sodium hydroxide using phenolphthalein gave the molecular weight values 230.7, 231.2 and 232.1, which are quite close to the actual molecular weight of 212.18. Pyrolysis of 3,5-dimethylpyrazolyl-1-succinic acid at 250-270° gave pure 3,5-dimethylpyrazole in 76% yield.

3,5-Dimethyl-1-(2'-cyanoethyl)-pyrazole. 14.4 g of 3,5-dimethylpyrazole was heated in a sealed ampule with 35 ml of acrylonitrile at 105° for 10 hours. The excess acrylonitrile was removed and the residue vacuum distilled. We obtained 20.8 g (93%) of 3,5-dimethyl-1-(2'-cyanoethyl)-pyrazole with b. p. 114-115° (1 mm) and m. p. 49° (from octane).

Found %: C 64.74, 64.79; H 7.21, 7.31. $C_8H_{11}N_3$. Calculated %: C 64.39; H 7.44.

The picrate had m. p. 160° (from alcohol).

To a solution of 2.5 g of acetylacetone in 5 ml of alcohol was carefully added 2.5 g of monocyanoethylated hydrazine, while the temperature was not allowed to rise above 50°. After removal of the solvent and the water formed in vacuum, the residue crystallized as coarse yellow crystals with m. p. 38°. The substance did not give a picrate, dissolved in water and was evidently the monohydrazone of the enol form of acetylacetone. When

recrystallized from octane or treated with concentrated hydrochloric acid, it was converted into 3,5-dimethyl-1-(2'-cyanoethyl)-pyrazole described above, with m. p. 51° and b. p. 115° (1 mm).

Found %: C 64.69, 64.73; H 7.55, 7.67. $C_8H_{11}N_3$. Calculated %: C 64.39; H 7.44.

The picrate had m. p. 160° (from alcohol).

Found %: C 44.36, 44.54; H 3.74, 3.88. $C_8H_{11}N_3 \cdot C_6H_3O_7N_3$. Calculated %: C 44.44; H 3.73.

A mixed melting point with the picrate described above was not depressed.

3,5-Diphenylpyrazolyl-1-succinic acid. A mixture of 11 g of 3,5-diphenylpyrazole and 5 g of maleic anhydride was heated for 1 hour at 160-175°. The reaction mixture was poured into 40 ml of boiling water and boiled for 15 minutes. On cooling, the crude substance crystallized and weighed 16.3 g (100%). After recrystallization from 500 ml of a mixture of dioxane and water (1:4) with the addition of 4 g of activated charcoal, the substance had m. p. 189-190° (in a sealed capillary).

Found %: C 67.50, 67.60; H 5.12, 5.15; N 8.04, 8.06. $C_{19}H_{16}O_4N_2$. Calculated %: C 67.85; H 4.79; N 8.33.

3(5)-Methyl-5(3)-phenylpyrazolyl-1-succinic acid. As in the previous experiment, from 13.8 g of 3(5)-methyl-5(3)-phenylpyrazole and 10 g of maleic anhydride we obtained 24.1 g (100%) of a substance with m. p. 180-182° (from water and in a sealed capillary).

Found %: C 61.50, 61.65; H 5.29, 5.39; N 10.44, 10.26. $C_{14}H_{14}O_4N_2$. Calculated %: C 61.30; H 5.15; N 10.21.

3,5-Dimethyl-4-bromopyrazolyl-1-succinic acid. A mixture of 3.5 g of 3,5-dimethyl-4-bromopyrazole and 2 g of maleic anhydride in 10 ml of dioxane was boiled for 6 hours. The reaction mixture was poured into 40 ml of water, 0.5 g of activated charcoal added and the product recrystallized. The substance, which crystallized slowly, weighed 5.4 g (95%) and had m. p. 151-152°.

Found %: C 36.82, 36.93; H 3.86, 3.94. $C_8H_{11}O_4N_2Br$. Calculated %: C 37.12; H 3.81.

3,4,5-Trimethylpyrazolyl-1-succinic acid. This product was obtained similarly to the 3,5-dimethyl-4-bromopyrazolyl-1-succinic acid described above in 95% yield and had m. p. 192-193° (from water).

Found %: C 52.51, 52.60; H 6.48, 6.39; N 12.14, 12.12. $C_{10}H_{14}O_4N_2$. Calculated %: C 52.84; H 6.24; N 12.38.

2,5-Di-(3,5-dimethylpyrazolyl-1)-hydroquinone. 9.6 g of 3,5-dimethylpyrazole and 5.6 g of p-benzoquinone were dissolved in 30 ml of dioxane and heated on a water bath for 1 hour. The reaction mixture was poured into 75 ml of water, the mixture stirred and the crystals collected. The yield was 8.2 g (61%). The substance was dissolved in 50 ml of 2N sodium hydroxide, boiled for 0.5 hours with 1 g of activated charcoal and precipitated from the filtrate with acetic acid. The sublimation temperature was about 230°. In a sealed capillary the product darkened at about 240°, and decomposed at 260° without melting.

Found %: N 18.46, 18.38. $C_{16}H_{20}O_2N_4$. Calculated %: N 18.66.

The picrate had m. p. 182-185° (from 50% alcohol).

Found %: N 18.40, 18.41. $C_{16}H_{20}O_2N_4 \cdot 2C_6H_3O_7N_3$. Calculated %: N 18.52.

2-(3,5-Dimethylpyrazolyl-1)-naphthohydroquinone. The substance was obtained similarly to 2,5-di-(3,5-dimethylpyrazolyl-1)-hydroquinone. From 7.8 g of α -naphthoquinone and 4.8 g of 3,5-dimethylpyrazole was obtained 8.8 g (70%) of the substance. After purification as described above, the substance had m. p. 248-251° (not sharp).

Found %: N 11.27, 11.28. $C_{15}H_{14}O_2N_2$. Calculated %: N 11.01.

Methyl ester of α -methyl- β -(3,5-dimethylpyrazolyl-1)-propionic acid. A mixture of 14.4 g of 3,5-dimethylpyrazole and 25 ml of methyl methacrylate was heated in an autoclave at 200° for 5 hours. Distillation of the reaction mixture in vacuum yielded 19.4 g (62%) of the addition product with b. p. 77-81° (14 mm) and m. p. 33°.

Found %: C 61.03, 61.12; H 8.41, 8.43. $C_{10}H_{10}O_2N_2$. Calculated %: C 61.21; H 8.22.

The picrate had m. p. 119° (from alcohol).

SUMMARY

1. It was shown that in contrast to oxazole, pyrazole, thiazole, imidazole and isoxazole do not undergo a Diels-Alder reaction.
2. Pyrazoles with a free NH group readily add at an activated double bond.

LITERATURE CITED

- [1] G. Ya. Kondrat'eva, Chem. Sci. and Ind., 2, 667 (1957).
[2] R. Wiley, N. Smith, D. Johnson, and J. Moffat, J. Am. Chem. Soc. 76, 4933 (1954), 77, 2572 (1955).
[3] I. I. Grandberg and A. N. Kost, J. Gen. Chem. 29, 656 (1959).*

Received March 3, 1958

* Original Russian pagination. See C.B. Translation.

DIENE HYDROCARBONS FROM UNSATURATED ALCOHOLS

III. CATALYTIC DECOMPOSITION OF ALLYL CARBINOL

Yu. A. Gorin, V. S. Ivanov, T. G. Pushnova and

V. V. Ziatogurskaya

Leningrad State University

Literature data devoted to the catalytic conversion of allylcarbinol may be divided into two groups, dehydration of allylcarbinol with the formation of divinyl and conversion of allylcarbinol accompanied by destruction of the carbon skeleton (formation of propylene and carbon). Dehydration of allylcarbinol into divinyl by the action of concentrated sulfuric acid on the alcohol was observed by Grishkevich-Trokhimovskii [1]. The formation of divinyl was also noted on the addition of allylcarbinol to 50% sulfuric acid at 120° [2]. Data on the conversion of allylcarbinol into divinyl is available in the patent literature. The catalysts used for dehydration of allylcarbinol were anhydrous alum at 150-300° [3] or acid phosphates, not containing free H_3PO_4 , at temperatures above 200° [4]. Allylcarbinol is an intermediate in synthetic rubber production in Germany by the aldol method [5]. It is formed by the elimination of one molecule of water from butandiol-1,3. It is isolated and dehydrated to divinyl on the phosphate catalyst (a mixture of sodium phosphates and phosphoric acid on coke) [6]. In this case the allylcarbinol vapor is diluted with steam. An increase in divinyl yield from a dehydration in the presence of hydrogen has also been noted [7]. On the other hand, Doyarenko [8] established that the main decomposition products of allylcarbinol over Al_2O_3 at 400-450° were propylene, carbon and water. She reported that divinyl and vinylacetaldehyde were secondary products. A comparison of the data presented shows that phosphate catalysts promote dehydration leading to the formation of divinyl. Catalysts based on aluminum oxide cause predominant decomposition of allylcarbinol, which leads to the appearance of destruction products (propylene, carbon, etc.).

In our previous investigations we studied the catalytic conversion of α, β -unsaturated alcohols over various dehydrating catalysts [9]. In the present work it was shown that under the conditions under which an α, β -unsaturated alcohol (crotyl) readily loses water to form divinyl in 85-88 mole % yield on the alcohol passed (over one of the dehydrating components of S. V. Lebedev's catalyst, B_2), allylcarbinol (a β, γ -unsaturated alcohol) mainly undergoes decomposition with the formation of propylene and formaldehyde.

For the dehydration of allylcarbinol, we tested the dehydrating components of S. V. Lebedev's catalyst, B and B_2 , and also a silica gel-tantalum catalyst which consisted of Ta_2O_5 (2%) deposited on silica gel. Under the same conditions over the silica gel-tantalum catalyst, crotyl alcohol gave an 83.3 mole % yield of divinyl [9]. Crotyl alcohol was converted into divinyl in the highest yield over one of the dehydrating components of S. V. Lebedev's catalyst, B_2 . The presence of small amounts of divinyl in the catalyzed gas from the decomposition of allylcarbinol over this catalyst showed that here catalytic dehydration only occurred to an insignificant extent. These results agree completely with the data of Ratner and Yafarova [10], who dehydrated allylcarbinol catalytically over B_2 and activated Al_2O_3 . The results obtained show that the catalysts we took, which promoted the formation of divinyl from crotyl alcohol, did not show selectivity in this direction in their action on allylcarbinol.

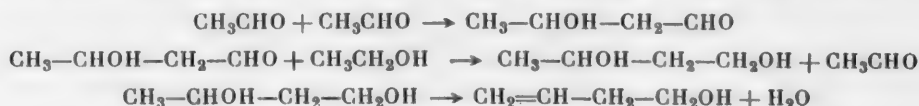
As has already been said, the main direction of allylcarbinol conversion over the modified dehydrating component, B_2 , was decomposition with the formation of propylene and formaldehyde. The presence of

propylene in the gas was demonstrated by the presence of 1,2-dibromopropane amongst the bromination products of a gas sample. The presence of formaldehyde in the condensate was established by the specific condensation reaction with β -naphthol [11] and also the preparation of the 2,4-dinitrophenylhydrazone. It is probable that a similar decomposition occurred in the experiments of Doyarenko, who found propylene and carbon in the decomposition products of allylcarbinol over Al_2O_3 but did not detect formaldehyde [8].

The fraction of butyl alcohols, a side product from the production of divinyl by S. V. Lebedev's method, usually contains 5-9% of unsaturated C_4 alcohols. Until recently it was considered that this unsaturated impurity was crotyl alcohol [12]. It was established [13] that besides crotyl alcohol, the fraction also contained the isomeric allylcarbinol. It has been proposed that divinyl formation is possible from ethyl alcohol in the S. V. Lebedev process [14] by direct condensation of acetaldehyde (in the enol form) with ethyl alcohol to give allylcarbinol, which then loses water. The results of the present work, which show that allylcarbinol predominantly undergoes propylene decomposition under the action of the dehydrating component of S. V. Lebedev's catalyst, do not support this scheme.

As was established previously, the conversion of butanediol-1,3 on the dehydration component of S. V. Lebedev's catalyst proceeds with the formation of a considerable amount of propylene [15]. Methyl alcohol was detected in the liquid products obtained in the decomposition products of butanediol-1,3 over the S. V. Lebedev catalyst [16]. From a comparison of these data with the results of the present investigation, it may be postulated that butanediol-1,3 first loses one molecule of water and is converted into allylcarbinol. Under the action of the dehydrating component of S. V. Lebedev's catalyst, the latter decomposes with the formation of propylene and formaldehyde. The formaldehyde formed is reduced to methyl at the expense of the hydroxyl groups of butanediol-1,3 or allylcarbinol. The possibility of the reduction of carbonyl compounds in the presence of alcohols under the conditions of the S. V. Lebedev process was demonstrated previously [17].

Summarizing the data of papers [10, 13, 15 and 16] and of the present work, it may be postulated that the formation of allylcarbinol in the S. V. Lebedev process proceeds by the following scheme.



However, this type of conversion is only undergone by a very small part of the acetaldehyde formed in the process and due to this, the amounts of butanediol-1,3 (intermediate) and allylcarbinol and also of methyl alcohol formed (side products in the process) are extremely small.

EXPERIMENTAL

1. Starting materials and apparatus. The starting allylcarbinol was obtained by two methods, through an organomagnesium compound and by dehydration of butanediol-1,3. In the first case, the starting materials were allyl bromide and magnesium turnings, from which allylmagnesium bromide was prepared. The latter in ether solution was reacted with formaldehyde obtained from polyoxymethylene [18]. By this method 100 g of crude allylcarbinol were obtained. The product obtained was purified via the boric esters [19]. The purification consisted of binding the alcohol as the borate, from which nonalcoholic impurities contained in the crude product were distilled in vacuum (130 mm). The purified borate was decomposed with water to give alcohol and boric acid. The allylcarbinol, liberated as an oily layer, was dried with baked potassium carbonate and distilled.

B. p. 112-114.5°, d_4^{20} 0.8444, n_D^{20} 1.4219.

Found %: OH 24.0. $\text{C}_4\text{H}_8\text{O}$. Calculated %: OH 23.6.

α -Naphthylurethan, m. p. 76-76.5° (from petroleum ether).

Found %: N 5.85. $\text{C}_{15}\text{H}_{15}\text{O}_2\text{N}$. Calculated %: N 5.81.

According to literature data: b. p. 112.5-113.5°, d_4^{20} 0.8475, n_D^{20} 1.4224 [20]; naphthylurethan m. p. 76-77° [21].

Catalytic Decomposition of Allylcarbinol

Expt. No.	Catalyst	Diluent and degree of dilution (mole)	Temp. of expt.	Rate of alcohol input (ml. hour ⁻¹ ml. of catalyst ⁻¹)	Alcohol passed (in g)	Gas obtained (in ml)	Composition of gas (without air)(volume %)						Yield of C ₄ H ₈ (in mole %)	
							CO ₂	C ₂ H ₄ +C ₂ H ₆	C ₂ H ₄	CO	H ₂	CH ₄	C ₄ H ₈	on allylcarbinol passed
1	B	Nitrogen 1:3	350°	0.70	2.53	0.46**	2.2	65.6	3.0	3.0	3.0	2.2	21.1	9.9
2	B ₂	—	350	0.70	24.06	2.86	2.2	77.4	0.9	—	2.4	0.5	13.0	4.5
3	SiO ₂ + 1% Ta ₂ O ₅	—	370	0.53	4.22	0.95	2.1	58.1	1.4	—	6.0	1.9	25.1	19.6
4	SiO ₂ + Ta ₂ O ₅	Nitrogen 1:3	370	0.53	4.22	0.78**	4.1	29.6	—	3.4	3.4	5.4	54.1	27.4
														62.1***
														85.0
														58.2
														83.3

* Data presented for comparison.

** The volume of gas without nitrogen is given.

*** Yield of divinyl from crotyl alcohol in an experiment without nitrogen dilution.

**** Yields on reacted allylcarbinol in experiment (in mole %): C₄H₈ 13.0, C₂H₆ 77.6, HCHO 34.2.

According to analysis by the bromide-bromate method, the allylcarbinol content of the product obtained was 97.6%. A mixed melting point of the urethan with the α -naphthylurethan of allylcarbinol obtained by incomplete dehydration of butanediol-1,3 was not depressed.

In the second case, allylcarbinol was synthesized by incomplete dehydration of butanediol-1,3 [22]. The dehydrating agent used was p-toluenesulfonic acid (m. p. 103.5°), obtained by hydrolysis of p-toluenesulfonyl chloride. The liquid dehydration products of butanediol-1,3 were salted out and the aqueous layer separated; the upper layer was dried over baked potassium carbonate and distilled on a column with an efficiency of 100 theoretical plates (determined by Bushmakina's method [23]). A fraction was isolated which corresponded to allylcarbinol and which was also purified via the borate.

B. p. 112-114°, d_4^{20} 0.8392, n_D^{20} 1.4206, % OH 23.4. Allylcarbinol content, determined by the bromide-bromate method, 93.2%.

It should be noted that the liquid dehydration products of butanediol-1,3 also yielded methylvinylcarbinol in an amount which was a tenth of that of allylcarbinol. The fraction corresponding to crotyl alcohol was not taken off.

Experiments on the catalytic conversion of allylcarbinol were performed on an apparatus which was described in one of our previous communications [9]. A quartz catalyst tube was loaded with 10 ml of catalyst. The temperature of the experiment was measured with a chromel-alumel thermocouple, connected to a contact galvanometer of the ÉRM-47 type, which also served to maintain the given temperature. The experimental procedure and the analysis of the gaseous reaction products were described previously [9].

2. Catalysts. The catalysts used were certain of the dehydrating components of the S. V. Lebedev catalyst, B and B₂, and a silica gel-tantalum catalyst, consisting of tantalum pentoxide deposited on silica gel (98% SiO₂ + 2% Ta₂O₅). This catalyst is used in the industrial production of synthetic rubber in the USA for the preparation of divinyl from a mixture of alcohol and acetaldehyde [24].

3. Catalytic decomposition of allylcarbinol. The results of experiments on the catalytic conversion of allylcarbinol are presented in the table. In experiment 2 (over catalyst B₂) the reaction products were examined in more detail. The gas was brominated in chloroform solution so as to isolate the liquid

bromides. The latter were dried with calcium chloride and distilled. After removal of the chloroform, the bulk of the bromides boiled at 139-140° and had d_4^{20} 1.9138, n_D^{20} 1.5192. According to literature data for 1,2-dibromopropane [25]: b. p. 141.6°, d_4^{20} 1.933, n_D^{20} 1.5203. Thus, the unsaturated C₃ + C₄ compounds, determined in the gas analysis by absorption in 83% H₂SO₄, were practically propylene alone. The propylene yield, calculated on the alcohol passed was 26.5 mole % and on the alcohol decomposed, 77.6 mole %.

The amount of unreacted alcohol (calculated on the allylcarbinol) in dried condensate was determined by acetylation and the bromide-bromate method. We found 17.9% OH, which corresponds to an alcohol content of 75.9%. The allylcarbinol content of the condensate, determined by the bromide-bromate method was 74.9%. The aldehyde in the condensate yielded a 2,4-dinitrophenylhydrazone, which melted at 166-167° after several recrystallizations [26]. The amount of formaldehyde was determined according to Foss's method [11] by condensation of the formaldehyde with β -naphthol and determining the weight of product obtained. The formaldehyde was determined by means of hydroxylamine hydrochloride in Lunge bottles, through which the gas was passed. The formaldehyde yield on the alcohol passed was 11.7 mole % and on the alcohol reacted, 34.2 mole %.

SUMMARY

1. A study was made of the conversion of allylcarbinol over certain dehydrating components of S. V. Lebedev's catalyst at 350° and also over a silica gel-tantalum catalyst at 370°. It was shown that divinyl is formed from allylcarbinol in only insignificant amounts under these conditions.

2. It was established that over the dehydrating components of S. V. Lebedev's catalyst (B and B₂) the decomposition of allylcarbinol to propylene and formaldehyde occurs predominantly. The data obtained do not support the proposal that divinyl may be formed via allylcarbinol in the S. V. Lebedev process.

3. It was proposed that allylcarbinol is formed in the S. V. Lebedev process by incomplete dehydration of butanediol-1,3. In its turn, the latter may be obtained by reduction of acetaldol.

LITERATURE CITED

- [1] E. Grishkevich-Trokhimovskii, J. Rus. Chem. Soc. 48,901 (1916).
- [2] L. W. Newman and H. N. Rydon, J. Chem. Soc. 1936, 261.
- [3] French Pat. 686446 (1929); Zbl. 1931, I, 1952; Canadian Pat. 300572 (1929); Zbl. 1933, II, 1250.
- [4] British Pat. 345270 (1928); Ch. A., 26, 157 (1932).
- [5] O. B. Litvin, Synthetic Rubber Technology, State Chem. Press, 155 (1950).*
- [6] J. W. Reppe, Acetylene Chemistry, N. Y. 10 (1949).
- [7] W. Breuers and H. Luttrupp, Buna, Berlin, 31 (1954).
- [8] M. N. Doyarenko, J. Russ. Chem. Soc., 58, 22 (1926); Ber. 60, 1536 (1927).
- [9] Yu. A. Gorin, V. S. Ivanov, E. S. Bogdanova and É. A. Pyäivinen, J. Gen. Chem. 28, 169 (1958);** Yu. A. Gorin, V. S. Ivanov and E. K. Khrennikova, J. Gen. Chem. 28, 1421 (1958).**
- [10] T. V. Ratner and R. L. Yafarova, Report Syn. Rubber Factory Lab. (1955).
- [11] K. Foss, P. Graeve, and P. Thomas, C.R., 200, 1450 (1935).
- [12] S. V. Lebedev, L. A. Livshits, Z. K. Remiz and A. A. Shul'ts, Trans. Exp. Plant, Lit, "B" 4, 3 (1935).
- [13] T. V. Ratner, I. F. Rachinskaya and G. M. Sinaiskii, Report Syn. Rubber Factory Lab., (1953); T. V. Ratner, I. F. Rachinskaya and I. G. Grigor'eva, Report Syn. Rubber Factory Lab., (1953).
- [14] G. M. Kogan and V. M. Svetozarova, Coll. Trans. All-Union Synthetic Rubber Scientific Research Institute for 1954; 6, 54 (1957).
- [15] Yu. A. Gorin, K. N. Charskaya and A. V. Bochkareva, J. Gen. Chem., Coll. II, 818 (1953).

* In Russian.

** Original Russian pagination. See C.B. Translation.

- [16] Yu. A. Gorin, V. S. Ivanov and B. E. Myuller, Coll. Trans. All-Union Synthetic Rubber Scientific Research Institute for 1954; 6, 64 (1957).
- [17] Yu. A. Gorin, Trans. All-Union Synthetic Rubber Scientific Research Institute, 1, 5 (1948).
- [18] H. Gilman, E. W. Towne, and H. L. Jones, J. Am. Chem. Soc., 55, 4689 (1933).
- [19] S. M. Rivkin, Caoutchouc and Rubber, No. 3, 16 (1937).
- [20] A. Juvala, Ber. 63, 1989 (1930).
- [21] G. Eglinton, E. R. H. Jones, G. H. Mansfield, and M. C. Whiting, J. Chem. Soc. 1954, 3197.
- [22] S. F. Birch and D. T. McAllan, J. Chem. Soc. 1951, 2556.
- [23] L. N. Bushmakina, J. Gen. Chem 21, 1197 (1951).*
- [24] B. B. Corson, H. E. Jones, C. E. Welling, J. A. Hinckley, and E. E. Stahly, Ind. Eng. Ch. 42, 359 (1950).
- [25] Chem. Handbook, State Chem. Press, 2, 396, 1099 (1951).
- [26] V. S. Johnson, R. D. Shennan and R. A. Reid. Organic Reagents for Organic Analysis, Foreign Lit. Press, 127 (1948). [Russian Trans.].

Received February 10, 1958

* Original Russian pagination. See C.B. Translation.

REACTIONS OF α - and β -CHLOROETHYLETHYLDICHLOROSILANES WITH SILICON UNDER DIRECT SYNTHESIS CONDITIONS

S. I. Sadykh-zade and A. D. Petrov

Institute of Organic Chemistry, Academy of Sciences, USSR and

Institute of Chemistry, Academy of Sciences, Azerbaidzhan SSR

We recently established the possibility of preparing polyfunctional organosilicon compounds by direct synthesis from α -, β - and γ -chloroalkylsilane chlorides [1]. It was shown that on reaction with silicon (at 370-380°), together with the synthesis products, $\text{Cl}_3\text{SiCH}_2\text{CH}_2\text{Cl}$ and $\text{Cl}_3\text{SiCHClCH}_3$ formed the dehydrochlorination product of these silane chlorides, trichlorovinylsilane, in 5% yield. At the same time, in the case of the γ -chloroalkylalkyldichlorosilanes, $-\text{Cl}_2(\text{CH}_3)\text{SiCH}_2\text{CH}_2\text{CH}_2\text{Cl}$ and $\text{Cl}_2(\text{CH}_3)\text{SiCH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{Cl}$ [II] - the yield



of dehydrochlorination products varied from 26% (for the former) to 58% (for the latter). Considering that the higher yield of the dehydrochlorination products in the two latter reactions was caused not so much by greater ease of formation of the β -alkenylchlorosilanes (in comparison with α -alkenylchlorosilanes) as by the replacement of one of the chlorines by alkyl in the trichlorosilyl group, we undertook the present investigation. The results of it, which are presented in Tables 1 and 2, confirmed our hypothesis. Actually, the yield of alkenylsilanes, products of β -decomposition ($\text{CH}_2=\text{CHSiCl}_2$) and dehydrochlorination [$(\text{C}_2\text{H}_5)(\text{CH}_2=\text{CH})\text{SiCl}_2$] were 18-27% here. The synthesis products, polyfunctional silane chlorides (tetrachlorodisilanes and hexachlorotrisilanes) were formed in yields of 24-25%.

EXPERIMENTAL

α - and β -Chloroethylethyldichlorosilanes were obtained in 600 g amounts by chlorination of diethyldichlorosilane with irradiation by an ultraviolet lamp. They were distilled to give α - and β -isomers on a column. In the direct synthesis at 370-380° over an alloy (80% Si and 20% Cu), the material was passed through the furnace at 25 g/hour under the conditions described previously [1]. Besides determination of the physicochemical properties, the reaction products (isolated by fractionation on a column) were identified by methylation (with CH_3MgI) of the silane chlorides formed [the properties of these compounds (IX-XIV) are presented in Table 2]. Ethylvinylidichlorosilane was converted into triethylvinylsilane:

b. p. 146-147° at 754 mm, d_{20}^{20} 0.7776, n_D^{20} 1.4335. Literature data [2]: b. p. 146°, n_D^{20} 1.4330, d_{20}^{20} 0.7767.

SUMMARY

It was shown that under the conditions of direct synthesis, α - and β -chloroethylethyldichlorosilanes give an 18-27% yield of β -decomposition and dehydrochlorination products [$\text{CH}_2=\text{CHSiCl}_2$ and $(\text{C}_2\text{H}_5)(\text{CH}_2=\text{CH})\text{SiCl}_2$] and a 24-25% yield of synthesis products, polyfunctional silane chlorides (tetrachlorodisilanes and hexachlorotrisilanes).

TABLE 1

Starting compound (C ₄ H ₉)Cl ₃ SiCHClCH ₃			Starting compound (C ₄ H ₉)Cl ₃ SiCH ₂ CH ₂ Cl		
reaction products	boiling point	content (in %)	reaction products	boiling point	content (in %)
(I) SiCl ₄	57—58°	1.0	(I) SiCl ₄	56—58°	1.0
(II) Cl ₃ SiCH=CH ₂	91—92	8.0	(II) Cl ₃ SiCH=CH ₂	91—92	10.0
(III) Cl ₃ SiCH ₂ CH ₃	98—98.5	5.0	(III) Cl ₃ SiCH ₂ CH ₃	98—99	5.0
(IV) (C ₂ H ₅)Cl ₂ SiCH=CH ₂	120—122	10.0	(IV) (C ₂ H ₅)Cl ₂ SiCH=CH ₂	120—122	17.0
(V) (C ₂ H ₅) ₂ SiCl ₂	127—128	15.0	(V) (C ₂ H ₅) ₂ SiCl ₂	127—128	6.0
(VI) (C ₂ H ₅)Cl ₂ Si—CH—SiH(Cl) ₂ CH ₃	205.0	7.5	(VI) (C ₂ H ₅)Cl ₂ Si—CH ₂ —CH ₂ —SiH(Cl) ₂	209—210	6.0
(VII) (C ₂ H ₅)Cl ₂ Si—CH—SiCl ₃ CH ₃	67 (1 mm)	11.0	(VII) (C ₂ H ₅)Cl ₂ Si—CH ₂ —CH ₂ —SiCl ₃	221.0	13.0
(VIII) [(C ₂ H ₅)Cl ₂ Si—CH—CH ₃] ₂ SiCl ₂	146—148 (2 mm)	7.5	(VIII) [(C ₂ H ₅)Cl ₂ Si—CH ₂ —CH ₂ —CH ₂ —SiCl ₂] ₂	149—150 (1 mm)	5.0
Intermediate fractions and losses	—	35.0	Intermediate fractions and losses	—	37.0

TABLE 2

No. of com- pound	Formula	Name of compound	B. p. (pressure in mm)	n_D^{20}	M_n		Found (%)			Calc. (%)		
					found	calc.	C	H	Si	C	H	Si
(VI)	$(C_2H_5Cl)_2Si-CH(CH_3)-SiHCl_2$	1-Methyl-1-ethyl- dichlorosilyl-1-di- chlorosilylmethane	205 (750)	1.4765	56.80	57.21	—	—	—	—	—	21.87
(VII)	$(C_2H_5Cl)_2Si-CH(CH_3)-SiCl_3$	1-Methyl-1-ethyl- dichlorosilyl-1-tri- chlorosilylmethane	67 (1)	1.4810	60.90	61.21	—	—	—	—	—	19.27
(VIII)	$(C_2H_5Cl)_2Si-CH(CH_3)-SiCl_3$	3,3,5,5,7,7-Hexa- chloro-4,6-dimeth- yl-3,5,7-trisilylnonane	146-148 (2)	1.4995	92.64	93.62	—	—	—	—	—	20.43
(VI)	$(C_2H_5Cl)_2Si-CH(CH_3)-SiCl_2$	1-Ethyl-1-dichlorosilyl- 2-dichlorosilyl- 2-trichlorosilyl- ethane	209-210 (750)	1.4748	56.60	57.21	—	—	—	—	—	21.87
(VII)	$(C_2H_5Cl)_2Si-CH_2CH_2SiCl_3$	1-Ethyl-1-dichlorosilyl- 2-trichlorosilyl- ethane	221 (750)	1.4750	61.15	61.21	—	—	—	—	—	19.27
(VIII)	$[(C_2H_5Cl)_2SiCH_2CH_2]_2SiCl_2$	3,3,6,6,9,9-Hexachlo- ro-3,6,9-trimethyl- undecane	149-150 (1)	1.4930	92.46	93.62	—	—	—	—	—	20.43
(IX)	$(C_2H_5)(CH_3)_2Si-CH(CH_3)-SiH(CH_3)_2$	1-Methyl-1-dimeth- ylsilyl-1-dimethyl- ethylsilylmethane	48 (10)	1.4373	58.24	58.69	55.49	12.73	31.99	55.49	12.14	32.37
(X)	$(C_2H_5)(CH_3)_2Si-CH(CH_3)-Si(CH_3)_3$	1-Methyl-1-trimeth- ylsilyl-1-dimethyl- ethylsilylmethane	60 (10)	1.4405	62.98	63.06	57.53	12.82	30.11	57.75	12.30	29.96
(XI)	$(C_2H_5)(CH_3)_2Si-CH(CH_3)-Si(CH_3)_3$	3,3,4,5,5,6,7,7-Octa- methyl-3,5,7-tri- silylnonane	108-109 (2)	1.4605	95.09	95.80	58.46	12.55	29.75	58.33	12.50	29.16
(XII)	$(C_2H_5)(CH_3)_2Si-CH(CH_3)-Si(CH_3)_3$	1-Dimethylsilyl-2- dimethylsilyl- ethane	50 (10)	1.4320	58.50	58.69	55.41	12.65	32.27	55.49	12.14	32.37
(XIII)	$(C_2H_5)(CH_3)_2SiCH_2CH_2Si(CH_3)_3$	1-Trimethylsilyl-2- dimethylsilyl- ethane	58 (10)	1.4300	62.96	63.06	57.73	12.88	29.85	57.75	12.30	29.96
(XIV)	$[(C_2H_5)(CH_3)_2SiCH_2CH_2]_2Si(CH_3)_2$	3,3,6,6,9,9-Hexa- methyl-3,6,9-tri- silylundecane	129-130 (10)	1.4525	95.71	95.80	58.40	12.50	29.10	58.33	12.50	29.16

LITERATURE CITED

- [1] S. I. Sadykh-zade, E. A. Chernyshev and V. F. Mironov, Proc. Acad. Sci. USSR, 105, 496 (1955); A. D. Petrov, S. I. Sadykh-zade, E. A. Chernyshev and V. F. Mironov, J. Gen. Chem., 26, 1248 (1956);* A. D. Petrov, S. I. Sadykh-zade, V. A. Ponomarenko, B. A. Sokolov and Yu. P. Egorov, J. Gen. Chem. 27, 2479 (1957).*
- [2] S. N. Ushakov and A. M. Itenberg, J. Gen. Chem. 7, 2495 (1937).

Received February 20, 1958

*Original Russian pagination. See C.B. Translation.

STEREOCHEMISTRY OF NITROGEN HETEROCYCLES

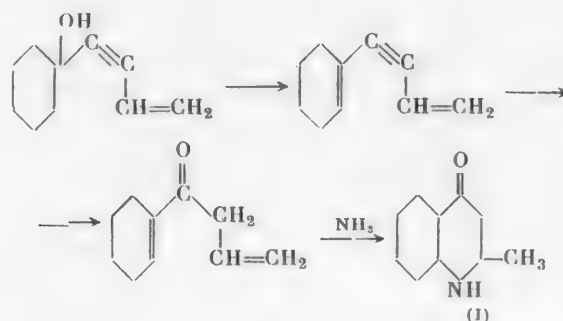
III. STEREOISOMERISM OF 2-METHYL-4-KETODECAHYDROQUINOLINE

D. V. Sokolov, G. S. Litvinenko and K. I. Khludneva

Instituté of Chemical Sciences, Academy of Sciences Kazak SSR

This communication is the continuation of a previously begun study of the stereoisomerism of 4-piperidones and the alcohols corresponding to them and of the syntheses of stereoisomeric local anesthetics of the piperidine series [1, 2]. In the first article we made a detailed study of the stereoisomerism of 2,5-dimethyl-4-piperidone and many of its derivatives. The oxidation of three stereoisomeric piperidols with the aim of preparing two racemates of 2,5-dimethyl-4-piperidone, however, did not give positive results since the secondary ketone formed apparently isomerized into the stable trans-form through the enol compound.

On the suggestion of the late Academician I. N. Nazarov, in the present work we chose as the subject of our stereochemical investigations the readily available 2-methyl-4-ketodecahydroquinoline (I), which is obtained from acetylene derivatives [3] by the scheme



This compound has three asymmetric carbon atoms and theoretically may exist in the form of four racemates. We obtained three of the four theoretically predicted racemates (II), (III) and (IV), designated α -, β - and γ -isomers, respectively, (scheme 1) and studied their properties and interconversion. The fourth, δ -isomer (V), could only be obtained in the form of its benzoyl derivative (Va). The physicochemical properties of the stereoisomeric ketones and also the melting points of their derivatives are presented in the table. Many fractional crystallizations of the mixture of hydrochlorides of (I) from anhydrous alcohol yielded two hydrochlorides (VII) and (VIII), which crystallized in different crystal forms and melted at 199 and 210°, respectively. Decomposition of the hydrochloride (VII) with an aqueous solution of sodium hydroxide or ammonia formed a mixture of α - and β -ketones, from which the stable α -isomer (II) with m. p. 62-63°, which is difficultly soluble in petroleum ether, was readily isolated in a predominant amount. On decomposition of the salt (VII) with solutions of sodium bicarbonate or potassium carbonate, together with the α -isomer we isolated up to 60% of the unstable β -isomer (III) with m. p. 38-39°, which is readily soluble in petroleum ether. The yields of the β -isomer were the same when the hydrochloride (VII) was obtained from the pure α -isomer (II). On prolonged storage, the β -isomer spontaneously isomerized into the stable α -isomer (II). The isomerization proceeded considerably more quickly in aqueous solution at room temperature and still more quickly on heating. When treated with HCl in aqueous or alcohol solution, the α - and β -isomers formed only the

water. When dried in a vacuum desiccator over solid sodium hydroxide or calcium chloride, it lost three molecules of water and was completely converted into the γ -isomer (IV), which, like its hydrate (VI), gave the original hydrochloride (VIII) on treatment with hydrogen chloride.

An attempt to isomerize the stable γ -ketone (IV) into the unstable δ -isomer (V) through the hydrochloride (VIII) [similar to the isomerization of the α -ketone (II) into the β -ketone (III) through the hydrochloride (VII)] and to isolate the isomerization product as the free base (V) was unsuccessful in these experiments, apparently due to the exceptional instability of the latter. However, if the hydrochloride (VIII), obtained from the γ -ketone (IV) was benzoyleated in aqueous solution at the moment of its decomposition with alkali, then a mixture of the N-benzoyl derivatives of the γ - and δ -isomers was formed and the yield of the benzoyl derivative (Va) of the unstable δ -isomer with m. p. 117-118° reached 65%. The analogous derivative of the γ -ketone (IVa) melted at 139° and was obtained in quantitative yield by the action of benzoyl chloride on the γ -isomer in dry benzene.

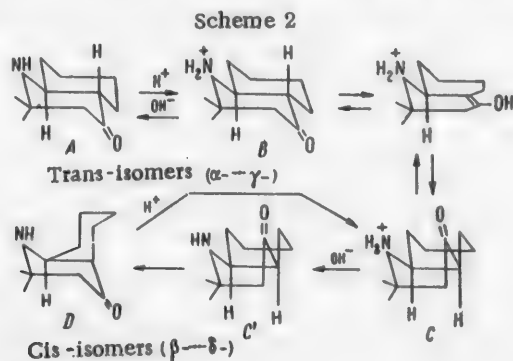
Thus, the isomers of 2-methyl-4-ketodecahydroquinoline (I) may be divided into two pairs, α - β - and γ - δ -, within which interconversions are possible, but such conversions are not possible between these pairs.

The capacity of the γ -ketone (IV) for readily forming a crystalline hydrate (VI) made it possible to simplify the method and considerably shorten the time for separating the original mixture of isomers (I). When the mixture of isomers (I) was dissolved in water, the bulk of the hydrate (VI) crystallized and this yielded, as described above, the γ -ketone (IV), which formed approximately 50% of the original mixture of isomers. Crystallization of the residue from petroleum ether separated the α - and partially the β -isomers with a total yield of 40-42%.

From what has been said above, it is obvious that the original mixture of isomers of 2-methyl-4-ketodecahydroquinoline (I) consisted mainly of the stable α - and γ -isomers (II and IV) and partially of the less stable β -isomer (III). Apparently, the very unstable δ -isomer (V) is absent from the mixture. As regards the problem of whether, in the closure of the piperidine ring (see scheme), the more stable α - and γ -isomers (II and IV) are formed immediately or whether the less stable β - and δ -isomers (III and V) are formed initially (due to trans addition of the amino groups at the double bond of the cyclohexane ring), it is impossible to answer this at the moment since the δ -isomer (V) is very rapidly converted into the γ -isomer (IV) and the α - and β -isomers are connected by interconversions through the hydrochloride, into which 2-methyl-4-decahydroquinoline (I) is converted during its synthesis for separation from neutral compounds.

According to the principles of conformational analysis [4-6] and their application to piperidine derivatives [7, 8], it is to be expected that the stable α - and γ -isomers of 2-methyl-4-ketodecahydroquinoline (II) and (IV) (like trans-decalone) have the most thermodynamically favorable conformations of two chairs with equatorial (e, e) trans coupling of the piperidine and cyclohexane rings, differing from each other in the steric position of the methyl radical.

The fact that the unstable ketones (III) and (V) are formed from the stable ones (II) and (IV) through the corresponding hydrochlorides (VII) and (VIII), gives grounds for considering that in an aqueous solution each of the hydrochlorides exists in not one, but two, conformations, B and C, which are interconverted through the enol form and are in a state of equilibrium (Scheme 2). Under the action of the electrostatic action of the positively



charged nitrogen N^+ and the electronegative O of the $C=O$ dipole, the conformation of the cation B, corresponding to the structure of the stable trans isomers (II and IV) may isomerize into the conformation of two beds, which is only possible for a cis configuration. Under the action of alkali, the cation C forms the unstable system C^* , which isomerizes into conformation D with two chairs, due to steric repulsion. The latter, consequently, expresses the structure of the unstable β - and δ -isomers, which must thus belong to the cis series of ketones. All these isomerizations can be accomplished smoothly on models.

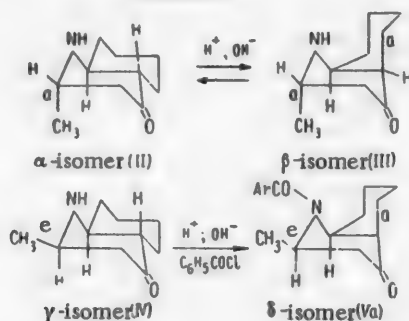
The considerable yields of the β - and δ -isomers (III and Va) in comparison with the α - and γ -isomers, obtained in the decomposition of the hydrochlorides (VII) and (VIII) with carbonates [and benzylation in the case of the δ -isomer (V)] indicates that the equilibrium in the system $B \rightleftharpoons C$ in aqueous solution is displaced towards the cis cation C and that consequently the strength of the electrostatic attraction predominates over the steric forces in this case. From the known rule that the more stable trans isomers have the least solubility, it may be supposed that evaporation of aqueous solutions of the hydrochlorides (VII) and (VIII) would crystallize hydrochlorides of the trans series (conformation A) and thus in the crystalline state, the hydrochlorides (VII) and (VIII) are probably derivatives of the corresponding α - and γ -isomers (II) and (IV).

The study of the conditions of isomerization of the stable α - and γ -ketones, (II) and (IV), into the unstable β - and δ -isomers, (III) and (Va), through the hydrochlorides, which we described and which is apparently general for unsymmetrically substituted γ -piperidones, has not as yet yielded quantitative characteristics and further studies will be made in this direction.

The identity of the dipole moments (2.6 D, see Table 1) of the α - and γ -ketones on the one hand and the β -ketone, as a representative of the unstable isomers, on the other, indicates that the piperidine ring undoubtedly has a chair form in all four racemates of 2-methyl-4-ketodecahydroquinoline. Consequently, in the end, the isomerization by the scheme $A \rightarrow D$ is reduced to a change in equatorial-equatorial trans coupling of the piperidine and cyclohexane rings of the α - and γ -isomers into the less stable equatorial-axial cis coupling of the β - and δ -ketones.

The greater values of the refractive index and the specific gravity of the α -isomer and the smaller ones of the γ -isomer are apparently explained by differences in the steric position of the methyl radical. According to Auwer's rule [9] and its interpretation in the light of configurational-analysis principles [6], the methyl radical must occupy an axial position in the first case and an equatorial one in the second. Since in the isomerization of the α - and γ -ketones into the unstable β - and δ -isomers, the piperidine ring retains its initial chair form and only the character of the ring coupling is changed, the steric position of the methyl radicals in each pair of interisomerizable ketones must remain unchanged and correspond to the structure of the stable isomers. From what has been said, the steric structures of the stereoisomeric ketones (II), (III), (IV) and (Va) may be expressed by the following conformations (Scheme 3).

Scheme 3



The reverse isomerization of the β -isomer (III) into the α -isomer (II) is apparently accomplished under the effect of the basic properties of the secondary amino group nitrogen atom. Lacking basic properties, the benzoyl derivatives of the β - and δ -isomers (IIIa) and (Va) are practically stable and do not undergo isomerization during recrystallization from organic solvents.

EXPERIMENTAL

2-Methyl-4-ketodecahydroquinoline (I) was obtained from vinyl ethynylcyclohexanol-1 by the procedure described previously [3] and had the following constants:

b. p. 88-90° at 1 mm, 128-130° at 11 mm, 138-140° at 18 mm, n_D^{20} 1.5003, d_4^{20} 1.0272, M_R 47.92; calc. 47.59.

Resolution of the mixture of 2-methyl-4-ketodecahydroquinoline isomers (I) through the hydrochlorides. Preparation of the hydrochlorides of the α - (VII) and γ -isomers (VIII). 50 g of the liquid mixture of isomers (I) was dissolved in 200 ml of anhydrous alcohol and neutralized with an alcohol solution of dry hydrogen chloride. The mixture of crystals obtained was fractionally crystallized many times from anhydrous alcohol (more than 80 recrystallizations) and this yielded two fractions of crystals. The first fraction (17.9 g; 29% of the mixture) was the hydrochloride of the α -isomer (VII) as fine needles with m. p. 198-199°.

Found %: N 7.10, 7.19. $C_{10}H_{18}ONCl$. Calculated %: N 6.87.

The second fraction of crystals (19 g) was the hydrochloride of the γ -isomer (VIII) as coarse, transparent small bars with m. p. 209-210°.

Found %: N 7.10, 6.98. $C_{10}H_{18}ONCl$. Calculated %: N 6.87.

A mixture of the two hydrochlorides melted at 194-195°.

α -Isomer of 2-methyl-4-ketodecahydroquinoline (II). 15.6 g of the hydrochloride (VII) with m. p. 198-199° was dissolved in 80 ml of water and treated first with 10.6 ml (90%), and then with excess ammonia. Each time the base was exhaustively extracted with ether. The remains of it were salted out with sodium chloride and also transferred into ether. After drying with potassium carbonate, removal of the solvent and recrystallization of the residues from petroleum ether, the three ether extracts yielded successively 6.91, 3.73 and 1.5 g of the α -isomer (II) with m. p. 62-63° with a total yield of 12.2 g (95.2%).

Found %: C 71.71, 71.64; H 10.14, 9.87; N 8.43, 8.31. $C_{10}H_{17}ON$. Calculated %: C 71.81; H 10.25; N 8.38.

The α -isomer (II) was readily soluble in water, alcohol, ether, benzene, acetone and chloroform and less readily so in petroleum ether. It crystallized from a small amount of water in an anhydrous state. In water and alcohol solutions it gave a red color with sodium nitroprusside.

The hydrochloride of the α -isomer (II) was obtained in 94% yield by neutralization of the base with an alcohol solution of dry hydrogen chloride; the fine, colorless needles had m. p. 198-199° (from anhydrous alcohol); a mixed melting point with the hydrochloride (VII), obtained from the original piperidone (I), was not depressed.

The picrate of the α -isomer was obtained in 95% yield by mixing equivalent amounts of alcohol solutions of the base and picric acid; the yellow bars had m. p. 168-169° (from alcohol).

Found %: N 14.28, 14.28. $C_{16}H_{20}O_5N_4$. Calculated %: N 14.14.

The oxime hydrochloride was obtained in 70% yield by mixing equivalent amounts of the α -isomer (II) and hydroxylamine hydrochloride in anhydrous alcohol. The substance crystallized from anhydrous alcohol with 1/2 a molecule of alcohol and melted at 218-219° in a sealed tube.

Found %: C_2H_5OH 8.85. $C_{10}H_{19}ON_2Cl \cdot \frac{1}{2} C_2H_5OH$. Calculated %: C_2H_5OH 9.52.

When dried in a vacuum desiccator, the oxime hydrochloride melted at 226-227° (with decomp.).

Found %: N 12.77, 12.63. $C_{10}H_{19}ON_2Cl$. Calculated %: N 12.81.

1-Benzoyl-2-methyl-4-ketodecahydroquinoline α -isomer (IIa) was obtained by two methods. a) By the Schotten-Baumann method. With stirring and cooling, 0.64 g of benzoyl chloride was added to a mixture of 0.5 g of the α -isomer (II) with m. p. 62-63° and 1.8 g of 10% aqueous sodium hydroxide solution. The reaction mixture was ground with a glass rod until the smell of benzoyl chloride disappeared. The benzoylation product was separated, washed with water, dried and recrystallized from benzene. We obtained 0.6 g (74%) of colorless, aggregated plates with m. p. 137-138°.

Found %: C 74.76, 74.96; H 7.66, 7.57; N 5.50, 5.39. $C_{17}H_{21}O_2N$. Calculated %: C 75.24; H 7.80; N 5.16.

b) Benzoylation in a water-benzene mixture. At a temperature of 13-15°, a solution of 116 g of potassium carbonate in 110 ml of water was added over a period of 2 hours with stirring to a solution of 70.4 g of hydrochloride (VII) in 200 ml of water and 51 g of benzoyl chloride in 300 ml of benzene, contained in a flask. The mixture was stirred for a further 2 hours and the precipitate then separated, washed first with water and then with benzene, dried and recrystallized from benzene. We obtained 46.7 g of benzamide (IIa) with m. p. 137-138°, which did not depress the melting point of the sample obtained above. The benzene solution, which had an alkaline reaction, was washed with hydrochloric acid, dried with potassium carbonate and evaporated to 80 ml. On standing, the solution deposited a further 33.3 g of (IIa) with m. p. 137-138°. In all, 80 g (85%) of benzamide (IIa) was obtained in this way. In addition, after considerable evaporation and recrystallization of the residue, the benzene mother solution yielded 1.1 g of the benzoyl derivative of the β -isomer (IIIa) with m. p. 131-132° (see below).

Isomerization of the α -isomer of 2-methyl-4-ketodecahydroquinoline (II) through the hydrochloride (VIII). Preparation of the β -isomer (III). a) 36.0 g of the hydrochloride (VII) with m. p. 198-199°, obtained from the pure α -isomer (II), was dissolved in 160 ml of water and decomposed with solid sodium bicarbonate (18.5 g). The base was extracted repeatedly with ether and the remains of it salted out with potassium carbonate and also extracted with ether. Drying the combined ether extracts with magnesium sulfate, removal of the solvent and recrystallization of the mixture of isomers from petroleum ether yielded 11.1 g of the α -isomer (II) with m. p. 62-63°. The mother solution was evaporated to small volume and on standing in the cold it deposited 16.3 g (55.3%) of coarse, colorless crystals of the β -isomer with m. p. 38-39°.

Found %: C 71.79, 71.54; H 10.32, 10.12; N 8.58, 8.40. $C_{16}H_{17}ON$. Calculated %: C 71.81; H 10.25; N 8.38.

A mixture of the α - and β -isomers melted at 38-55°.

Decomposition by the given procedure of the hydrochloride (VII), isolated from the original mixture of isomers (I), gave approximately the same yields of the α - and β -isomers (II) and (III).

b) Isomerization in excess base. 10.2 g of the α -isomer (II) with m. p. 62-63° was dissolved in 20 ml of water and neutralized to congo with concentrated hydrochloric acid. After the addition of 1 g of the α -isomer (II), the solution was heated under reflux on a boiling water bath for 10 hours. The cooled solution was treated with excess potassium carbonate and the base extracted with ether and dried by shaking with solid potassium carbonate for 15 minutes. After removal of the solvent, the mixture of base was recrystallized from petroleum ether to yield at first 4.2 g of the original α -isomer (II) with m. p. 62-63 and 6.17 g (55%) of the β -isomer (III) with m. p. 38-39°.

c) Isomerization in excess hydrochloric acid. A solution of 10 g of the α -isomer (II) in 40 ml of water was neutralized to congo with concentrated hydrochloric acid, a further 5 ml of acid added and the solution heated on a water bath for 1 hour. The cooled solution was treated with excess potassium carbonate and the base isolated as described above; recrystallization from petroleum ether yielded 3.9 g (38.8%) of the α -isomer (II) with m. p. 62-63° and 5.3 g (53%) of the β -isomer (III) with m. p. 38-39°.

The β -isomer (III) was readily soluble in organic solvents and somewhat less so in petroleum ether. It crystallized in an anhydrous state from a small amount of water. It slowly became wet at an air temperature of 25-30° and changed into a liquid, but on cooling it again crystallized and melted at 38-39°. On prolonged storage in a glass vessel, the α -isomer with m. p. 62-63° partially sublimed as fine platelets. The transition of the β -isomer into the α -isomer occurred considerably more rapidly (a few days) in aqueous solution at room temperature and when it was heated as a 10% aqueous solution for 1.5 hours, it was 30% isomerized into the α -isomer.

The hydrochloride was obtained in 95% yield by neutralization of an alcohol solution of the β -isomer with dry hydrogen chloride in anhydrous alcohol and formed fine needles with m. p. 198-199°, which did not depress the melting point of the hydrochloride obtained from the α -isomer.

The picrate was obtained in 90% yield by mixing equivalent amounts of the β -isomer and picric acid

in anhydrous alcohol; the fine yellow needles had m. p. 168-169° (from anhydrous alcohol). A mixture with the picrate of the α -isomer (m. p. 168-169°) melted at the same temperature.

Found %: N 13.75, 13.50. $C_{16}H_{20}O_3N_4$. Calculated %: N 14.14.

Oxime hydrochloride. When anhydrous alcohol solutions of 0.83 g of the β -isomer and 0.36 g of hydroxylamine hydrochloride were mixed, a mixture of oxime hydrochlorides was formed, which was fractionally crystallized from anhydrous alcohol to yield 0.42 g (40%) of the oxime hydrochloride of the α -isomer with m. p. 226-227° (a mixed melting point with the previously obtained isomer was not depressed) and 0.16 g (15%) of the oxime hydrochloride of the β -isomer with m. p. 218-219°. A mixture of these derivatives of the α - and β -isomers melted at 215-217°.

Found %: N 13.43, 13.26. $C_{10}H_{13}ON_2Cl$. Calculated %: N 12.81.

1-Benzoyl-2-methyl-4-ketodecahydroquinoline β -isomer (IIIa) was obtained by vigorous shaking of a solution of 0.5 g of the β -isomer in 2.7 ml of water with 0.5 g of the sodium bicarbonate and 0.63 g of benzoyl chloride. The reaction was accompanied by the liberation of carbon dioxide. When ground with a glass rod for one and a half hours, the oily substance initially formed crystallized and the smell of benzoyl chloride disappeared. The solid product was separated, washed with water, dried and recrystallized from benzene. We obtained 0.5 g (64%) of (IIIa) with m. p. 131-132°. A mixture of this with the analogous derivative of the α -isomer (IIa) melted at 105-108°.

Found %: C 75.54, 75.71; H 7.34, 7.31; N 5.14, 5.24. $C_{17}H_{21}O_2N$. Calculated %: C 75.24; H 7.80; N 5.16.

The γ -isomer of 2-methyl-4-ketodecahydroquinoline (IV). 10.2 g of the hydrochloride of 2-methyl-4-ketodecahydroquinoline (VIII) with m. p. 209-210° was dissolved in 35 ml of water and decomposed with excess solid potassium carbonate. The base was extracted with ether, dried with potassium carbonate and, after removal of the solvent, recrystallized from petroleum ether (b. p. 40-60°). We obtained 7.6 g of the γ -isomer (IV) as coarse colorless crystals with m. p. 41-42°.

Found %: C 71.90, 71.80; H 10.22, 10.30; N 8.37, 8.44. $C_{16}H_{17}ON$. Calculated %: C 71.81; H 10.25; N 8.38.

The γ -isomer (IV) melted on grinding in a mortar when mixed with the α - and β -isomers; it was readily soluble in organic solvents and somewhat less so in petroleum ether. It was stable to storage and slowly sublimed on the walls of the vessel as colorless, elongated plates with the same melting point. In contrast to the α - and β -isomers, it dissolved in water with the evolution of heat and the formation of a difficultly soluble crystalline trihydrate (V) with m. p. 55-56° (see below) and crystallized from water in this form. In contrast to the α - and β -isomers (II) and (III), solutions of the γ -isomer in water and alcohol did not give the red color characteristic of ketones with sodium nitroprusside.

The hydrochloride of the γ -isomer was obtained in 96% yield by neutralization of an alcohol solution of the base with an absolute alcohol solution of dry hydrogen chloride; the coarse, thick needles had m. p. 209-210° (from anhydrous alcohol). A mixed melting point with the hydrochloride (VIII), obtained in the separation of the original mixture of isomers (I) and melting at the same temperature, was not depressed. A mixture with the hydrochloride of the α -isomer (VIII) (m. p. 198-199°) melted at 194-195°.

The picrate was obtained by mixing alcohol solutions of the γ -isomer and picric acid; the fine yellow crystals had m. p. 173-174° (from anhydrous alcohol).

Found %: N 14.19, 13.96. $C_{16}H_{20}O_3N_4$. Calculated %: N 14.14.

The oxime hydrochloride of the γ -isomer was obtained in quantitative yield by the procedure described above; the colorless crystals had m. p. 237-238° (with decomp.).

Found %: N 12.90, 12.72. $C_{10}H_{11}ON_2Cl$. Calculated %: N 12.81.

1-Benzoyl-2-methyl-4-ketodecahydroquinoline γ -isomer (IVa). A solution of 1.4 g of benzoyl chloride in 20 ml of benzene was added to a solution of 3.34 g of the γ -isomer (IV) in 10 ml of dry benzene. After 2 hours, we separated 1.9 g of the hydrochloride of the γ -isomer (VIII) with m. p. 209-210°, which did not depress

the melting point of an authentic sample. From the evaporated benzene solution crystallized 2.66 g (98%) of the benzoyl derivative of the γ -isomer (IVa) with m. p. 138-139°. Mixtures of this substance with the analogous N-benzoyl derivatives of the α -isomer (IIa) (m. p. 137-138°) and the β -isomer (IIIa) (m. p. 131-132°) showed strong depression of the melting points and melted at 108-112°.

Found %: C 74.58, 74.52; H 7.60, 7.59; N 5.45, 5.38. $C_{17}H_{21}O_2N$. Calculated %: C 75.24; H 7.80; N 5.16.

Benzoylation of the γ -isomer (IV) by the Schotten-Baumann method gave the same benzamide (IVa) with m. p. 138-139°, but in lower yield.

Hydrate of the γ -isomer of 2-methyl-4-ketodecahydroquinoline (VI). a) 20.5 g of the hydrochloride of the γ -isomer (VIII) with m. p. 209-210° was dissolved in 70 ml of water and decomposed by shaking with the equivalent amount (13.9 g) of solid potassium carbonate. The crystalline mass formed was separated, recrystallized from water and dried. We obtained 15.8 g of the hydrate (VI) in the form of coarse, aggregated plates with m. p. 55-56°, which consisted of a compound of the γ -isomer (IV) with 3 molecules of water.

Found %: C 54.05, 54.18; H 10.40, 10.41; N 6.61, 6.56; H_2O 24.0. M 220.5. $C_{10}H_{17}ON \cdot 2H_2O$. Calculated %: C 54.27; H 10.47; N 6.32; H_2O 24.4, M 221.4.

b) 12.7 g of the γ -isomer was dissolved in 137 g of water. The crystals which precipitated after 2 days standing were separated and dried in air. We obtained 13.46 g (80%) of the hydrate (VI) with m. p. 55-56°, which did not depress the melting point of the sample above.

The hydrate (VI) was difficultly soluble in water and in aqueous solution it did not give a reaction for a carbonyl group with sodium nitroprusside. It dissolved in benzene and benzine with the loss of water and the formation of turbid solutions. When dried in a vacuum desiccator over solid sodium hydroxide or calcium chloride it lost water and was quantitatively converted into the γ -isomer (IV) with m. p. 41-42°; it formed the same derivatives as the γ -isomer (IV).

Isomerization of the γ -isomer of 2-methyl-4-ketodecahydroquinoline (IV) through the hydrochloride (VIII). Preparation of 1-benzoyl-2-methyl-4-ketodecahydroquinoline δ -isomer (Va). Into a three-necked flask fitted with a mechanical stirrer and a dropping funnel was introduced 44.82 g (0.22 mole) of hydrochloride (VIII) with m. p. 209-210° in 70 ml of water, 46.43 g (0.33 mole) of benzoyl chloride and several crystals of benzamide (Va). With vigorous stirring and cooling with cold water (5-10°), over a period of 25 minutes a solution of 22.0 g (0.55 mole) of sodium hydroxide in 128 ml of water was poured into the flask and then the contents of the flask were stirred for 35 minutes. The crystalline mass was collected and washed first with water and then with ether. When it was dissolved in acetone, 3.82 g of the original hydrochloride (VIII) with m. p. 209-210° separated. On standing, the acetone mother liquor deposited crystals, which were recrystallized three times from acetone to give 35.3 g (64.6%) of (Va) with m. p. 117-118°.

Found %: C 74.09, 74.21; H 7.47, 7.38; N 5.30, 5.40. $C_{17}H_{21}O_2N$. Calculated %: C 75.24; H 7.80; N 5.16.

The aqueous solution remaining after separation of the benzoylation products was saturated with solid sodium hydroxide and extracted with benzene. After separation of the inorganic products and evaporation, from the benzene solution crystallized 7.67 g (14%) of the previously described benzoyl derivative of the γ -isomer (IVa) with m. p. 138-139° and a mixture of this with the benzoyl compound of the δ -isomer (Va) melted at 105-109°. The yield of the benzoyl compound (Va) depended to a considerable extent on the establishment of equilibrium of the conformation of the hydrochloride (VIII) in the aqueous solution and, consequently, on the time from solution of the hydrochloride in water to benzoylation with the same times of addition and stirring, equal to 25 and 55 minutes, respectively.

Starting materials: 20 g of hydrochloride (VIII) in 31 ml of water, 9.8 g of NaOH in 57 ml of water and 20.6 g of C_6H_5COCl .

Beginning of Reaction	Yield of (Va)
10 minutes	60.4,
25 "	67.3,
41 hours	69.5.

An increase in the time of addition of the sodium hydroxide and subsequent stirring of the reagents until the smell of benzoyl chloride disappeared, as a rule, strongly lowered the yield of (Va).

Resolution of the mixture of isomers of 2-methyl-4-ketodecahydroquinoline (I) in the form of the hydrates of the γ - (VI) and α - (II) isomers. To 33 g of the liquid mixture of isomers (I) was added 16.5 g (2:1) of water. After solution, which was accompanied by heat evolution, the solution was left to crystallize. After 4 days the crystals were separated, washed with water and dried. We obtained 17.2 g (39.4% of the mixture) of the hydrate of the γ -isomer (VI) with m. p. 55-56°. The aqueous mother solution was saturated with potassium carbonate. The base was extracted with ether, dried with potassium carbonate and vacuum distilled after evaporation of the solvent. We obtained 19.3 g of a mixture of isomers and crystallization of this from petroleum ether (b. p. 50-60°) yielded 8.1 g (24.5%) of the α -isomer (II) with m. p. 62-63°. Isolation of the hydrate (VI) and the α -isomer (II) from the residual mixture of isomers was performed 3 more times as described above. In all, we isolated 21.1 g (48.3%) of the hydrate (VI) with m. p. 55-56° and 13.7 g (41.5%) of isomer (II) with m. p. 62-63°; 2.0 g (5.7%) of the mixture remained unresolved. In certain experiments on the resolution of (I), besides (VI) and (II), it was possible to obtain a small amount of the β -isomer (III) with m. p. 38-39°.

A change in the ratio of amino ketone (I) and water from 1:0.5 to 1:5 decreased the yield of hydrate (VI) after 4 days standing from 39.4 to 24.6%. Crystallization of the hydrate (VI) was considerably accelerated by the addition of a seed of (VI). In this case the mixture could be crystallized completely with vigorous stirring after only 3 hours and after standing for a day, the yield of hydrate (VI) reached 38-40%.

SUMMARY

1. All four theoretically possible isomer racemates of 2-methyl-4-ketodecahydroquinoline were obtained as the base or its derivatives.
2. Conditions were found for interconversions of the stable isomers into the unstable ones and back.
3. On the basis of conformational-analysis principles, definite steric structures were ascribed to these isomers and a possible mechanism for their interconversion was proposed.

LITERATURE CITED

- [1] I. N. Nazarov, D. V. Sokolov and V. N. Rakcheeva, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1954, 80.*
- [2] I. N. Nazarov, D. V. Sokolov and G. S. Litvinenko, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1954, 95.*
- [3] I. N. Nazarov and V. A. Rudenko, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1948, 610.
- [4] W. Klyne, Progress in Stereochemistry, London, 1, 36 (1954).
- [5] D. R. Barton and R. C. Cookson, Quart. Rev., 10, 44 (1956).
- [6] I. N. Nazarov and L. D. Bergel'son, Prog. Chem., 26, 3 (1957).
- [7] R. Chaudhuri and A. K. Bose, Sci. a. Culture, 19, 135 (1953).
- [8] A. K. Bose and R. Chaudhuri, Nature, 171, 652 (1953).
- [9] Von Auwers and Dersch, J. pr. Ch., 124, 209 (1930).

Received March 6, 1958

*Original Russian pagination. See C.B. Translation.

POLYENE SYNTHESIS

2-METHYL-3-PHYTYLNAPHTHOQUINONE-1,4 - VITAMIN K₁

I. K. Sarycheva, Yu. G. Molotkovskii, G. A. Vorob'eva and

N. A. Preobrazhenskii

Moscow Institute of Fine Chemical Technology

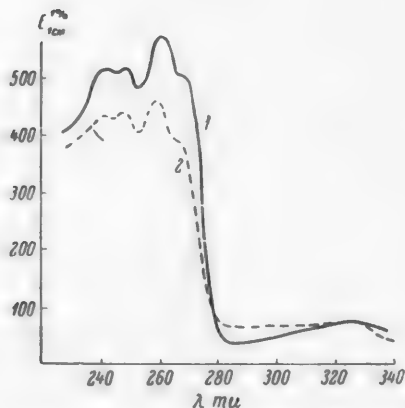
2-Methyl-3-phytylnaphthoquinone-1,4, vitamin K₁ (I), is an antihemorrhagic factor and is used in medical practice in the treatment of a number of diseases [1]. The green part of plants is the main source from which it is obtained [2]. The known syntheses of vitamin K₁ (I) are based on the reaction of 2-methylnaphthoquinone-1,4 or 2-methylnaphthohydroquinone-1,4 and its monosubstituted derivatives with natural phytol [3], which may be replaced completely by appropriate derivatives [4]. The 2-methylnaphthoquinone used in these syntheses is obtained from various β -substituted naphthalenes [5]. The method described in the literature for the preparation of phytol and also the isophytol isomeric to it are only of theoretical interest [6].

The present article describes a synthesis of vitamin K₁ (I) based on the condensation of 2-methylnaphthohydroquinone-1,4 (II) with isophytol (III) in the presence of boron trifluoride etherate [7].

The starting material for isophytol (III) was 2,6-dimethylundecatrien-2,6,8-one-10, pseudoionone (IV), synthesized by a convenient method proposed recently [8]. The pseudoionone was hydrogenated in an autoclave in the presence of Raney nickel catalyst into 2,6-dimethylundecanol-10 (V), which was oxidized with chromic mixture without isolation and purification. The 2,6-dimethylundecanone-10 (VI) obtained in this way was treated with sodium acetylide to give 2,6,10-trimethyldodecyn-11-ol-10 (VII); by means of acetoacetic ester [9], the latter was first 2,6,10-trimethylpentadecadien-10,12-one-14 (VIII) and then via 2,6,10-trimethylpentadecanol-14 (IX) into 2,6,10-trimethylpentadecanone-14 (X). (X) was condensed with sodium acetylide and the 2,6,10,14-tetramethylhexadecyn-15-ol-14 (XI) obtained was reduced in the presence of palladium catalyst [10] to isophytol (III). We should note that the physicochemical constants of the isophytol we synthesized on the basis of linalool [11] differed slightly from this sample, which is apparently connected with the predominance of different diastereoisomeric forms in them.

2-Methylnaphthohydroquinone-1,4 (II) was synthesized, starting from toluquinone and butadiene by a known method [12].

After appropriate treatment, the reaction product of isophytol (III) and 2-methylnaphthohydroquinone-1,4 (II), 2-methyl-3-phytylnaphthohydroquinone-1,4 (XII) was oxidized to (I). In its properties, the synthetic vitamin K₁ obtained corresponded to the natural product. Measurement of the ultraviolet spectrum of this compound in n-hexane gave an absorption curve agreeing with the absorption curve of natural vitamin K₁ (see figure).



UV absorption spectra of vitamin K₁ (I).
1) natural [13], 2) synthetic.



2,6,10-Trimethyldodecyn-11-ol-10 (VII). A fast stream of dry acetylene was passed through 200 ml of

anhydrous liquid ammonia and at the same time 2.2 g (0.025 g-at.) of sodium was added with stirring at such a rate that the reaction mixture did not acquire a stable blue color. The stream of acetylene was cut down, a solution of 18.15 g (0.0916 mole) of 2,6-dimethylundecanone-10 (VI) in 20 ml of ether added dropwise over a period of 30 minutes and the reaction mixture stirred for 2 hours and left for 12 hours at 18-19°. The thick orange mass formed was treated with 100 g of crushed ice and neutralized with sulfuric acid (d_4^{20} 1.395). The mixture formed layers. The upper, oily layer was separated and the substance extracted from the lower one with 200 ml of ether. The combined extracts were dried with sodium sulfate. After removal of the solvent, the residue was distilled. The yield was 14.41 g (70.17%).

B. p. 108-110° at 2 mm, d_4^{20} 0.8612, n_D^{20} 1.4547, MR_D 70.71; calc. 70.99

Found %: C 80.58, 80.24; H 12.42, 12.60. $C_{15}H_{22}O$. Calculated %: C 80.28; H 12.57.

2,6,10-Trimethylpentadecadien-10,12-one-14 (VIII). A mixture of 14.4 g (0.064 mole) of (VII) and 24.96 g (0.192 mole) of acetoacetic ester was heated in a stream of dry nitrogen at 160-170° for 50 hours. The unreacted acetoacetic ester was removed in vacuum (10 mm). The residue was distilled. The yield was 9.44 g (55.63%).

B. p. 107-110° at 0.2 mm, d_4^{20} 0.9094, n_D^{20} 1.4933. MR_D 84.53. $C_{18}H_{28}O$. Calculated 84.40.

2,6,10-Trimethylpentadecanone-14 (X) was prepared similarly to 2,6-dimethylundecanone-10 (VI). 9.44 g of (VIII) was hydrogenated to 2,6,10-trimethylpentadecanol-14 (IX), which, without isolation, was oxidized with a solution of 4.3 g of potassium bichromate in 30 ml of water in the presence of 15 ml of glacial acetic acid. To the mixture obtained was added 5.4 ml of sulfuric acid (d_4^{20} 1.395) with stirring in a stream of nitrogen. Appropriate treatment yielded 6.35 g (66.25%) of (X).

B. p. 111-113° at 0.2 mm, d_4^{20} 0.8494, n_D^{20} 1.4488, MR_D 84.72; calc. 85.33.

Found %: C 80.81; H 13.79. $C_{17}H_{26}O$. Calculated %: C 80.52; H 13.52.

2,6,10,14-Tetramethylhexadecyn-15-ol-14 (XI). To the sodium acetylide prepared from 0.55 g (0.0239 g-at.) of sodium and excess acetylene in 95 ml of liquid ammonia, was added a solution of 6.35 g (0.027 mole) of (X) in 15 ml of dry ether over a period of 20 minutes. The reaction mixture was treated as in the preparation of (VII). The yield was 3.55 g (50.97%).

B. p. 118-124° at 0.2 mm, d_4^{20} 0.8576, n_D^{20} 1.4567, MR_D 93.46; calc. 94.08.

Found %: C 81.68; H 13.28. $C_{20}H_{30}O$. Calculated %: C 81.59; H 13.01.

2,6,10,14-Tetramethylhexadecen-15-ol-14-isophytol (III). 3.55 g of (XI) in 30 ml of petroleum ether (b. p. 80-105° at 760 mm) was hydrogenated at 20° in the presence of 0.7 g of palladium catalyst [10] with mechanical mixing. When 302 ml of hydrogen (105% of the theoretical amount) had been absorbed, hydrogenation practically ceased. The catalyst was filtered off and washed with 12 ml of petroleum ether. The solvent was removed from the combined filtrates and the residue distilled. The yield was 2.80 g (78.34%).

B. p. 126-128° at 0.25 mm, d_4^{20} 0.8397, n_D^{20} 1.4514, MR_D 95.13; calc. 95.62.

Found %: C 81.17, 81.14; H 13.47, 13.48. $C_{20}H_{40}O$. Calculated %: C 81.02; H 13.60.

2-Methyl-3-phytylnaphthoquinone-1,4 - vitamin K₁ (I). Over a period of 10 minutes a solution of 2 g (0.00675 mole) of isophytol (III) in 2 ml of dioxane was added with stirring in a stream of dry nitrogen to a mixture of 2.2 g (0.0127 mole) of 2-methylnaphthohydroquinone-1,4 (II) in 8 ml of dry dioxane and 0.28 ml of boron trifluoride etherate. The reaction mixture was heated at 50° for 30 minutes, cooled to 18-20° and 40 ml of ether added. The solution obtained was then washed successively with 50 ml of water and 150 ml of a mixture of equal substance was extracted from the wash waters with 100 ml of ether. The combined extracts were dried with sodium sulfate. After removal of the solvent, 100 ml of n-hexane was added to the residue and the solution shaken mechanically for 30 minutes with 1.2 g of silver oxide. For purification, the solution of the compound obtained was filtered through a bed (2 g) of activated charcoal and passed through a column with 10 g of aluminum oxide. Removal of the n-hexane yielded 0.88 (28.95%) of substance:

n_D^{20} 1.6248; UV spectrum λ_{max} (in n-hexane) 242, 248, 260 m μ , $\epsilon_1^{1\%}$ 430, 438, 460.

Found %: C 82.60, 82.69; H 9.99, 10.13. $C_{31}H_{46}O_2$. Calculated %: C 82.58; H 10.29.

SUMMARY

1. A new method was developed for synthesizing 2,6,10,14-tetramethylhexadecen-15-ol-14 - isophytol.
2. On the basis of isophytol, vitamin K₁ was synthesized.

LITERATURE CITED

- [1] "Vitamins", The Food Industry Abroad, Coll. 2, Food Industry Press, 98 (1956).*
- [2] P. Karrer et al., *Helv. Chim. Acta*, 22, 310, 945, 1465, 1513 (1939); O. Isler, *Chimia*, 5, 249 (1951).
- [3] H. J. Almquist and A. Klose, *J. Am. Chem. Soc.* 61, 2557 (1939); E. A. Dolsy, *J. Biol. Ch.* 131, 357 (1939).
- [4] U. S. Pat., 2,325,681 (1943); Ch. A. 1944, 1077.
- [5] F. Fieser, *J. Am. Chem. Soc.*, 61, 2559 (1939); N. S. Nikolaev, *J. Gen. Chem.* 15, 654 (1945); *Sov. Rec. trav. chim.*, 59, 1021, 461 (1940); *Ber.* 73, 762 (1940).
- [6] T. Gottwalt, F. Fiescher, and K. Lowenberg, *Leib. Ann.* 475, 195 (1929); I. N. Nazarov and B. P. Gusev, *Bull. Acad. Sci. USSR*, 1957, 1267**; J. Weichert, J. Hodrova, and V. Kvita, *C. Listy*, 51, 568 (1957).
- [7] O. Isler and K. Doebel, *Helv. Chim. Acta*, 37, 225 (1954).
- [8] G. I. Samokhvalov, M. A. Miropol'skaya and N. A. Preobrazhenskii, *Proc. Acad. Sci. USSR*, 107, 103 (1956)**; *J. Gen. Chem.* 27, 2501 (1957)**.
- [9] W. Kimel, *J. Am. Chem. Soc.* 65, 1992 (1943); I. N. Nazarov and L. A. Yanovskaya et al., *Proc. Acad. Sci. USSR*, 114, 331, 553 (1957); V. Naves and P. Ardizio, *Bull. Soc. Chim.*, 1955, 1479.
- [10] H. Lindlar, *Helv. Chim. Acta*, 35, 446 (1952).
- [11] L. K. Sarycheva, G. A. Vorob'eva, N. A. Kuznetsova and N. A. Preobrazhenskii, *J. Gen. Chem.* 28, 654 (1958)**.
- [12] G. I. Ostrozhskaya, *J. Gen. Chem.*, 16, 1053 (1946).
- [13] R. Hirschmann, R. Miller, and N. Wendler, *J. Am. Chem. Soc.*, 76, 4592 (1954).

Received March 4, 1958

* In Russian.

** Original Russian pagination. See C.B. Translation.

THE REACTION OF BENZALDEHYDE AND CYCLOHEXANONE WITH BORIC ESTERS

V. K. Kuskov and A. N. Neverov

Moscow State University

On examining the reduction of aldehydes to alcohols by the Meerwein-Ponndorf-Verley method [1] it was found that not only aluminum alcoholates could be used but also various alkoxy derivatives of other elements [2], in particular, *n*-propyl, isopropyl, isobutyl and allyl borates [3]. Oppenauer [4] proposed the use of the Meerwein-Ponndorf-Verley reaction for the preparation of ketones.

In the present work we investigated the preparation of aldehydes from alkyl borates by the action of benzaldehyde on them and by the reaction of borates with cyclohexanone.

The reaction of butyl borate with benzaldehyde proceeded successfully if the butyraldehyde formed was removed by distillation. The yields of benzyl alcohol (apparently the hydrolysis product of benzyl borate) and of butyraldehyde were similar (71 and 62%). In addition, a mixture of high-boiling products was obtained. Propyl, isobutyl, isoamyl and glycol borates reacted analogously with the formation of propionaldehyde, isobutyraldehyde, isovaleraldehyde and glycolaldehyde, respectively. The results are given in the table.

In the reaction of benzaldehyde with cyclohexyl borate, the expected cyclohexanone was obtained in low yield; in addition, we obtained cyclohexanol and water and predominantly cyclohexane, apparently formed by dehydration of cyclohexanol or cleavage of the intermediate cyclohexyl metaborate [5]. In the reaction of cyclohexanone with propyl and butyl borates, aldehydes were not obtained and propyl and butyl alcohols, respectively, distilled over. The reaction mixture contained a mixture of products of which it was possible to identify only the product of crotonic condensation of cyclohexanone, α -cyclohexylidenecyclohexanone. Apparently, under the action of alkyl borates (aprotic acid!) cyclohexanone undergoes condensation more readily than reduction. Water liberated during the condensation hydrolyzes the boric esters and the corresponding alcohols are formed due to this.

EXPERIMENTAL

A mixture of 32 g of benzaldehyde and 23 g of *n*-butyl borate was slowly distilled from a flask with a pear fractionating head in such a way that the temperature of the vapor in the upper part of the fractionating head did not exceed 80°. The reaction required 16 hours to the end of distillation. The temperature in the flask gradually rose from 170–220°. The distillate was purified by fractionation on a column (18 theoretical plates). We obtained 13.5 g (62%) of butyraldehyde.

b. p. 75.7°, n_D^{20} 1.3843, d_4^{20} 0.8170. The dinitrophenylhydrazone had *m. p.* 122.5°, which agrees with literature data for butyraldehyde [6].

The residue from the flask was hydrolyzed with 100 ml of water and extracted several times with ether. The extract was washed twice with 3% sodium carbonate solution and then water, dried with baked magnesium sulfate and distilled. We obtained 23 g (71%) of benzyl alcohol with *b. p.* 203–206° (according to data [7]: *b. p.* (205°). Tribenzyl borate had *b. p.* 220–225° (3 mm) [6].

Analysis (by titration with 1 N NaOH in aqueous solution with mannitol).

Found % B 3.28. $C_{21}H_{22}O_3B$. Calculated % B 3.31.

Reaction of Boric Esters with Benzaldehyde and Cyclohexanone

Expt. No.	Boric ester	Reaction conditions			Reaction product	Yield (in %)	Boiling point	n _D ²⁰	M.p. of dinitro-phenyl-hydrazone	Literature data
		Temperature		Time (hours)						
		in reaction mixture	in distilling vapor							
Reactions with benzaldehyde										
1	n-Propyl	170-225°	68-83°	12	Propionaldehyde	76	48-49°	1.3639	155.5°	[8]
2	n-Butyl	170-220	80	18	Butyraldehyde	62.5	75.7	1.3843	122.5	[7]
3	Isobutyl	180-220	67-70	16	Isobutyraldehyde	70	62-65	1.3732	186	[9]
4	Isoamyl	170-220	60-80	5	Isovaleraldehyde	78.6	89-93	1.3897	108.5	[10, 11]
5	Glycol	200-300	70-95	7	Glycolaldehyde*	38.9	95-99	1.4326	162	[12]
6	Cyclohexyl	190-260	130-140	6	a) cyclohexene b) cyclohexanone	27 10	80-82 152-153	1.4450 1.4665	— 160	[13] [14]
Reactions with cyclohexanone										
7	n-Propyl	—	—	—	Propyl alcohol	58	96-97	1.3856	—	[14]
8	n Butyl	—	—	—	Butyl alcohol	40.6	117-118	1.3992	—	[15]

* In the reaction, 5 g of water distilled over, besides aldehyde.

** Contained cyclohexanol as impurity; cyclohexyl acetate obtained had b. p. 175°.

The other boric esters were reacted with benzaldehyde and cyclohexanone similarly. We used 32 g (0.3 mole) of cyclohexanone* to 0.1 mole of boric ester (Experiments 1-6, Table).

SUMMARY

1. An investigation was made of the reaction of benzaldehyde with boric esters and it was shown that it was possible to use the reaction for preparing the aldehydes corresponding to the esters.

2. It was shown that under analogous conditions, cyclohexanone formed the product of crotonic condensation, α -cyclohexylidenecyclohexanone, and aldehydes were not obtained.

LITERATURE CITED

- [1] Organic Reactions, II, 194 (1950)[in Russian].
- [2] H. Meerwein, B. Bock, Br. Kirschnick, W. Lens, and A. Migge, J. pr. Ch., (2) 147, 211 (1936).
- [3] H. G. Kuivila, S. C. Slack, and P. K. Sliterl, J. Am. Chem. Soc., 73, 123 (1951); M. H. Wuyts and A. Duquesne, Bull. Soc. Chim., 48, 77 (1939).
- [4] R. V. Oppenauer, Rec. trav. chim., 56, 137 (1937).
- [5] G. L. O. Connor and H. R. Nace, J. Am. Chem. Soc. 77, 1578 (1955).
- [6] A. Tschitschibabin, Ber., 37, 188 (1904).
- [7] V. K. Kuskov and V. A. Zhukova, Bull. Acad. Sci. USSR, Div. Chem. Sci. 1956, 733.**
- [8] H. Hartung and H. Adkins, J. Am. Chem. Soc., 49, 2520 (1927).
- [9] J. W. Bruhl, Lieb. Ann., 203, 18 (1895).
- [10] J. U. Nef, Lieb. Ann., 318, 162 (1901).
- [11] E. Semmler, Ber., 42 215 (1909).
- [12] H. Hartung, J. Am. Chem. Soc. 49, 2520 (1927).
- [13] S. S. Nametkin, J. Russ. Chem. Soc. 55, 59 (1923).
- [14] R. Schriener and F. Cox, J. Am. Chem. Soc. 53, 1602 (1931).
- [15] H. Meerwein, Lieb. Ann. 429, 144 (1918).

Received November 10, 1957

*This should presumably be benzaldehyde - Translator's note.

**Original Russian pagination. See C.B. Translation.

XXIII • NEW METHOD OF PREPARING QUINALDINE COMPOUNDS AND N-ARYLOUINALDINIUM SALTS

Novocherkasskii Polytechnical Institute

Quaternary salts of N-arylquinaldine were first studied by G. T. Pilyugin [2]. After that, Hezeltine[•] and Bruker [3] reported the formation of N-aryllepidinium salts (formed by the reaction of methyl vinyl ketone with diarylamines) and recently we also described the first members of the series studied, N-phenylquinolinium perchlorate, which was synthesized from diphenylamine and hydroacrylaldehyde [4]. The most readily available of the quinoline arylates are N-arylquinaldinium salts, which are readily isolated from reaction mixtures as the sparingly water-soluble perchlorates. Methods for their preparation are based on Skraup's reaction with crotonaldehyde [5] and also mainly on a modified Doebner-Miller reaction with the use of solvents (dioxane or benzene) or replacement of the acetaldehyde by vinyl ethers [6].

In connection with the above, for the preparation of certain previously undescribed 2,3-dialkylquinoline arylates from diarylamines and higher aliphatic aldehydes, we used a previously developed modification of a quinaldine synthesis [7], based on the separate performance of its two stages: the formation of dimers of vinyl-diphenylamine, apparently with a cyclic structure [8] and their dehydrogenation into quinolinium derivatives. The first stage was performed in a neutral medium and the second in an acid medium.

$$2\text{Ar}-\text{NH}-\text{Ar} + 2\text{RCH}_2\text{C}(=\text{O})\text{H} \longrightarrow 2\begin{matrix} \text{Ar} \\ \diagup \\ \text{N} \\ \diagdown \\ \text{Ar} \end{matrix} \text{CH}=\text{CH}-\text{R} \longrightarrow \begin{matrix} \text{Ar} & & \text{Ar} \\ | & & | \\ \text{N} & -\text{CH}- & \text{C}=\text{CH}-\text{N} \\ | & & | \\ \text{CH}_2\text{R} & & \text{R} \end{matrix}$$

$$\rightleftharpoons \begin{matrix} & \text{N}(\text{Ar})_2 \\ & | \\ \text{R}' \cdots & \text{C}_6\text{H}_3 \\ & | \\ & \text{N}(\text{Ar}) \\ & | \\ & \text{CH}_2\text{R} \end{matrix} \xrightarrow{+\text{HCl}} \begin{matrix} & \text{R} \\ & | \\ \text{R}' \cdots & \text{C}_6\text{H}_3 \\ & | \\ & \text{N}^+(\text{Ar}) \\ & | \\ & \text{CH}_2\text{R} \\ & | \\ & \text{Cl}^- \end{matrix} + \text{Ar}-\text{NH}-\text{Ar} + \text{H}_2$$

$\text{Ar} = \text{H}, \text{CH}_3, \text{C}_2\text{H}_5, \text{p-Cl}_3\text{H}_2; \text{Ar} = \text{C}_6\text{H}_5, \text{p-CH}_3\text{C}_6\text{H}_4, \text{p-C}_{10}\text{H}_7$

* * These names are not verified - Publisher's note.

The yield of products, isolated as the perchlorates, was 20-65% (1 molecule of quinoline arylate is formed from 2 molecules of the original diarylamine).

Primary aromatic amines, when used as the acyl derivatives, also give quinaldine products under analogous conditions. The reaction probably proceeds by a similar mechanism.

Thus, the reaction developed is a general method, allowing the use of various secondary and acylated primary aromatic amines and aliphatic aldehydes.

EXPERIMENTAL

1. N-Phenyl-2-ethyl-3-methylquinolinium perchlorate. 16.9 g of diphenylamine, 20 ml of propionaldehyde and 80 ml of nitrobenzene were boiled together gently for 7 hours. After this, 80 ml of conc. HCl (d 1.19) was added to the solution obtained and the mixture left at room temperature for 1-2 days and then slowly steam distilled. The unreacted secondary aromatic amine was thus completely converted to tar and remained on the walls of the distillation flask. The residual solution was decolorized by boiling with activated charcoal and evaporated to a volume of 80-100 ml. Perchloric acid was added when the solution cooled and a flocculent perchlorate appeared immediately. The yield was 11.2 g (65%).

M.p. 193-194° (from aqueous ethanol).

Found %: C 62.03; H 5.26; Cl 10.30. $C_{18}H_{18}O_4NCl$. Calculated %: C 62.17; H 5.21; Cl 10.19.

2. N-p-Tolyl-2-ethyl-3,6-dimethylquinolinium perchlorate. The reaction was performed as in experiment 1. From 1 g of p,p'-ditolylamine and 1.5 ml of propionaldehyde in 8 ml of nitrobenzene we obtained 0.45 g (47%) of perchlorate.

M. p. 207-209° (from water).

Found %: C 64.12; H 5.94; Cl 9.31. $C_{20}H_{22}O_4NCl$. Calculated %: C 63.93; H 5.90; Cl 9.44.

3. N-phenyl-2-ethyl-3-methyl-5,6-benzoquinolinium perchlorate. This product was obtained from 11 g of phenyl β -naphthylamine and 12 ml of propionaldehyde in 50 ml of nitrobenzene. The yield was 3.7 g (37%).

M. p. 198-199° (from water).

Found %: C 66.04; H 5.21; Cl 8.79. $C_{22}H_{20}O_4NCl$. Calculated %: C 66.39; H 5.07; Cl 8.91.

4. N- β -Naphthyl-2-ethyl-3-methyl-5,6-benzoquinolinium perchlorate. 7 g of β,β' -dinaphthylamine [10], 6 ml of propionaldehyde and 35 ml of nitrobenzene were used. The mixture was boiled gently for 6 hours, 40 ml of conc. HCl added when the solution cooled and the solvent removed immediately by steam distillation. The perchlorate was isolated as in experiment 1. The yield was 1.4 g (24%).

M. p. 196° (from aqueous acetone).

Found %: C 69.89; H 5.06; Cl 7.73. $C_{24}H_{22}O_4NCl$. Calculated %: C 69.71; H 4.97; Cl 7.92.

5. N-Phenyl-2-propyl-3-ethylquinolinium perchlorate. 6.9 g of diphenylamine, 25 ml of butyraldehyde and 80 ml of nitrobenzene were used. The reaction was performed as in experiment 4. The yield of perchlorate was 4.4 g (23%).

M. p. 185° (from aqueous ethanol).

Found %: C 64.10; H 5.96; Cl 9.51. $C_{20}H_{22}O_4NCl$. Calculated %: C 63.93; H 5.90; Cl 9.44.

6. N-Phenyl-2-propyl-3-ethyl-5,6-benzoquinolinium perchlorate. From 22 g of phenyl- β -naphthylamine and 25 ml of butyraldehyde in 75 ml of nitrobenzene we obtained 9 g (24%) of perchlorate.

M. p. 217-219° (from aqueous ethanol).

Found %: C 67.58; H 5.68; Cl 8.20. $C_{24}H_{24}O_4NCl$. Calculated %: C 67.67; H 5.68; Cl 8.32.

7. Naphthyl-2-propyl-3-ethyl-5,6-benzoquinolinium perchlorate. From 7 g of β,β' -dinaphthylamine and 7.5 g of butyraldehyde in 35 ml of nitrobenzene we obtained 1.2 g (20%) of perchlorate.

M. p. 168° (from water).

Found %: C 70.49; H 5.46; Cl 7.61. $C_{22}H_{26}O_4NCl$. Calculated %: C 70.66; H 5.52; Cl 7.45.

8. Quinaldine. A mixture of 5 g of formanilide, 12 g of acetal and 50 ml of nitrobenzene was boiled (temperature about 170°) for 1.5 hours. Then 15 ml of conc. HCl was added and the nitrobenzene removed by steam distillation. The residue was made alkaline and the base also steam distilled. The quinaldine was freed from aniline with phthalic anhydride [11]. The yield was 1.15 g (20%). The b. p. was 237-245°. The picrate had m. p. 190°.

9. 6,8-Dimethylquinaldine. 14.9 g of form-m-xylydide, 15 ml of paraldehyde and 100 ml of nitrobenzene were used. The mixture was heated for 3 hours at 180°. The yield was 5.3 g (31%). The b. p. was 261-267°. The picrate had m. p. 185°.

SUMMARY

1. Unknown 2,3-dialkylquinolinium derivatives were prepared.
2. It was shown that the reaction was applicable to various secondary and acylated primary arylamines and aliphatic aldehydes.

LITERATURE CITED

- [1] British Pat. 713255; Ch. A. 49, 2913 (1955).
- [2] G. T. Pilyugin, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1952, 353.*
- [3] U. S. Pat., 2,570,304; Ch. A. 46, 8681 (1952).
- [4] B. I. Ardashev and V. L. Minkdn, J. Gen. Chem., 29, 200 (1958).*
- [5] U. S. Pat. 2,578,303; Ch. A. 46, 8680 (1952); U. S. Pat. 2,646,433; Ch. A. 48, 5887 (1954).
- [6] G. T. Pilyugin and E. P. Opanasenko, J. Gen. Chem. 27, 1015 (1957).*
- [7] V. L. Minkdn and B. I. Ardashev, J. Gen. Chem. 28, 2556 (1958).*
- [8] L. P. Zalukaev, Proc. Acad. Sci. USSR, 110, 791 (1956).*
- [9] B. I. Ardashev, Prog. Chem. 23, 45 (1954).
- [10] E. Knoevenagel, J. pr. Ch. 89, 1 (1914).
- [11] B. A. Porai-Koshits, Author's certificate No. 47297 from July 30, 1936.

Received January 14, 1958

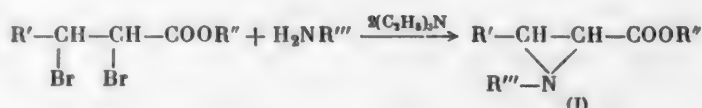
* Original Russian pagination. See C.B. Translation.

SOME 2-CYANOETHYLENEIMINES AND NITRILES OF α -HALO- β -AMINO ACID

V. K. Antonov

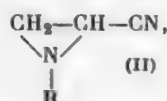
Institute of Experimental Pathology and Cancer Therapy,
Academy of Medical Sciences, USSR

Among the many derivatives of ethyleneimine, compounds containing a carboxyl group or groups genetically connected with it have been studied very little. Only in 1953 was a method developed for the synthesis of esters of ethyleneiminocarboxylic acids (I) by means of the reaction of primary amines with esters of α , β -dibromaliphatic acids [1].



This reaction was previously used for the synthesis of ethyleneimino ketones [2].

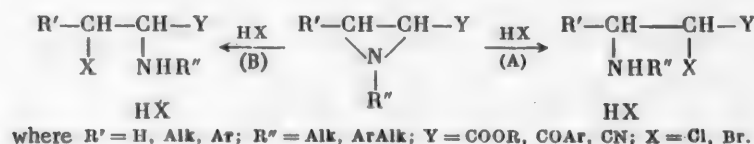
It seemed interesting to us to use this method [1] for the synthesis of 1-alkyl-2-cyanoethyleneimines (II), compounds which have not been described in the literature up to now, and to study their behavior in certain reactions specific for the ethyleneimino ring and cyano groups. For this purpose we condensed α , β -dibromopropionitrile with benzylamine, cyclohexylamine, methylamine and isopropylamine and actually obtained the corresponding 1-alkyl-2-cyanoethyleneimines (II) in all cases.



where $\text{R} = \text{CH}_2\text{C}_6\text{H}_5, \text{C}_6\text{H}_{11}, \text{CH}_3, \text{CH}(\text{CH}_3)_2$.

The reaction conditions were similar to those recommended for the preparation of esters of ethylene-carboxylic acids [1]. The yields, constants and analyses of the compounds obtained are presented in Table 1.

Opening with hydrohalic acids is a characteristic reaction of the three-membered ethyleneimine ring. Depending on the electron-donor properties of the substituents, ring opening may occur in two directions [1, 2, 3].



With esters of 3-phenylethyleneiminocarboxylic acids ($\text{Y} = \text{COOR}, \text{R}' = \text{C}_6\text{H}_5$) the opening usually occurs in direction (B) [3]. As a rule, in esters of ethyleneiminocarboxylic acids, unsubstituted in position 3 ($\text{Y} = \text{COOR}, \text{R}' = \text{H}$), the ring is opened in direction (A) [4, 5].

In the case of 1-alkyl-2-cyanoethyleneimines, one would apparently expect the formation of nitriles of α -halo- β -alkylamino acids. The 2-cyanoethyleneimines we synthesized were opened with hydrobromic acid in an ether solution. In all cases the expected hydrobromides of the nitriles of α -bromo- β -alkylaminopropionic acids were obtained (Table 2).

The structures of the substances obtained were confirmed by determination of the labile α -bromine atom by the liberation of I_2 from an acidified alcohol-acetone solution of KI [3,4,6]. It should be noted that the reaction of α -halonitriles with KI requires slightly longer heating than in the case of esters of α -haloacids (30-45 minutes instead of 15 minutes [4]), which is apparently connected with the lower lability of the halogen in halonitriles. The method made it possible to determine the α -bromine atom with an accuracy of up to 95% (Table 2).

Using 1-cyclohexyl-2-cyanoethyleneimine, we studied the hydrolysis of 2-cyanoethyleneimines. When hydrolyzed with 1 mole of aqueous alcoholic alkali, 1-cyclohexyl-2-cyanoethyleneimine was converted into the amide of 1-cyclohexylethyleneimine-2-carboxylic acid. We should note that the evolution of about 30% of NH_3 was observed. When excess alkali was used and the heating was prolonged (about 3 hours) the hydrolysis proceeded to the carboxylic acid (judging by the amount of NH_3 evolved); however, we were unable to isolate a salt of 1-cyclohexylethyleneiminocarboxylic acid in a pure state.

In conclusion we would like to express our deep thanks to A. Ya. Berlin for constant interest in the present work and valuable advice.

EXPERIMENTAL

1-Isopropyl-2-cyanoethyleneimine. 10.65 g (0.05 mole) of α, β -dibromopropionitrile was dissolved in 15 ml of dry benzene and a solution of 3.2 g (0.054 mole) of isopropylamine and 10.1 g (0.1 mole) of triethylamine in 15 ml of dry benzene added to the solution with stirring at 5-10°. The mixture was heated in an autoclave at 80° for 3 hours. The cooled mass was filtered free from the triethylamine hydrobromide precipitate and the latter carefully washed with dry benzene. The weight of the triethylamine hydrobromide was 16.7 g (92%). The filtrate was evaporated under reduced pressure and the residue vacuum distilled. The yield of 1-isopropyl-2-cyanoethyleneimine was 3.25 g. The other 2-cyanoethyleneimines were synthesized analogously (Table 1). In the case of benzylamine and cyclohexylamine, the reaction could be performed in an open vessel due to their high boiling point.

TABLE 1

1-Alkyl-2-cyanoethyleneimines $\begin{array}{c} CH_2-CH-CN \\ \backslash \quad / \\ N \quad R \end{array}$

R	Yield (in %)	B. p. (pressure in mm)	n_D	d_4	M_R		Found %		Calc. %	
					found	calc.	C	H	C	H
CH_3	34.5	47-48°(7)	1.4363*	0.9546*	22.50	22.23	58.20	7.27	58.50	7.36
$(CH_3)_2CH$	59	58-58.5 (9)	1.4346**	0.9049**	31.74	31.46	65.78	8.98	65.41	9.15
C_6H_{11}	51	105-106(6)	1.4796*	0.9795*	43.53	43.12	71.35	9.33	71.95	9.39
$C_6H_5CH_2$	39.5	125-126(6)	1.5319**	1.0432**	46.98	46.34	75.38	6.54	75.91	6.37

*At 22°.

**At 20°.

Hydrobromide of the nitrile of α -bromo- β -isopropylaminopropionic acid. 1 g of 1-isopropyl-2-cyanoethyleneimine was dissolved in 20 ml of dry ether and a stream of dry HBr passed in with cooling in ice water

until no more precipitate was formed. The mixture was left in a refrigerator for 2 hours, the ether decanted and the precipitate dissolved in 3 ml of boiling, anhydrous alcohol. Ether was added to the solution until a persistent turbidity was formed and the mixture heated to boiling and filtered. On standing in a refrigerator, the solution deposited fine prismatic crystals. The yield was 1.85 g. A second recrystallization from a mixture of alcohol and ether (2:1) yielded a substance with m. p. 109–110° (decomp.). The other hydrobromides of α -bromo- β -alkylaminopropionitriles were obtained similarly (Table 2).

TABLE 2

Hydrobromides of α -Bromo- β -alkylaminopropionitriles													
<div><div>$\begin{array}{c} \text{R}-\text{NH}-\text{CH}_2-\text{CH}-\text{CN} \\ \qquad \\ \text{HBr} \qquad \text{Br} \end{array}$</div></div>													
R	Yields (in %)	Melting point	Found %						Calc. %				
			C	H	Br			C	H	Br			
					total	ionic	α			total	ionic	α	
CH ₃	55	133.5—134.5°	19.96	3.50	65.79	33.05	31.71	19.69	3.30	65.52	32.76	32.76	
(CH ₃) ₂ CH	75	109—110	26.36	4.35	58.82	30.10	28.78	26.49	4.45	58.76	29.38	29.38	
C ₆ H ₁₁	67	176—177	35.48	5.17	51.70	23.20	21.48	34.61	5.18	51.22	22.61	22.61	
C ₆ H ₅ CH ₂	43	165—166	38.25	3.75	50.20	25.75	23.54	37.53	3.78	49.94	24.97	24.97	

*The substances were recrystallized from a mixture of ethanol and hexane (1:1); the melting points are uncorrected; all the substances melted with decomposition.

Hydrolysis of 1-cyclohexyl-2-cyanoethyleneimine. 0.5 g of cyanoethyleneimine was mixed with a solution of 0.14 g of NaOH in a mixture of 2 ml of water and 2 ml of C₂H₅OH. The mixture was boiled for 1.5 hours. The NH₃ liberated was trapped with 0.1 N HCl. The mass was then cooled and 5 ml of alcohol added. The solution was decanted from a small amount of tarry precipitate and evaporated to dryness in vacuum. After drying, the substance obtained weighed 0.4 g. After 2 recrystallizations from water, the amide of 1-cyclohexylethyleneimino-2-carboxylic acid melted at 129.5–130°. The yield was 0.25 g (47%).

Found %: C 64.20; H 9.47; N 15.93. C₉H₁₆ON₂. Calculated %: C 64.25; H 9.58; N 16.65.

Found, in g: NH₃ 0.01687. Calculated, in g: NH₃ 0.0566. NH₃ liberated, 29.8%.

0.5 g of the substance was hydrolyzed with 0.28 g of NaOH in 4 ml of 50% aqueous C₂H₅OH for 3 hours. Evaporation yielded a mixture of NaOH and an oily product, which could not be purified.

Found, in g: NH₃ 0.04941. Calculated, in g: NH₃ 0.0566. NH₃ liberated, 87.9%.

SUMMARY

- 1-Benzyl-, 1-cyclohexyl-, 1-isopropyl- and 1-methyl-2-cyanoethyleneimines were synthesized by the action of benzyl, cyclohexyl-, isopropyl and methylamines, respectively, on α , β -dibromopropionitrile.
- The action of dry hydrogen bromide on the 2-cyanoethyleneimines yielded the corresponding hydrobromides of α -bromo- β -alkylaminopropionitriles.
- Hydrolysis of 1-cyclohexyl-2-cyanoethyleneimine with aqueous alcoholic alkali gave the amide of 1-cyclohexylethyleneimino-2-carboxylic acid.

LITERATURE CITED

- [1] M. A. Stolberg, J. O'Neill, and T. Wagner-Jauregg, *J. Am. Chem. Soc.* 75, 5045 (1953).
- [2] N. H. Cromwell, R. D. Babson, and C. E. Harris, *J. Am. Chem. Soc.*, 65, 312 (1943); N. H. Cromwell, *Chem. Revs.* 38, 100 (1946).
- [3] H. Moreu, P. Chovin, and L. Petit, *Bull. Soc. Chim.*, 1955, 1573.
- [4] V. K. Antonov, *J. Gen. Chem.* 29, 306 (1959).*
- [5] K. Gundermann, *Angew. Ch.* 69, 400 (1957).
- [6] N. H. Cromwell and R. A. Wankel, *J. Am. Chem. Soc.*, 70, 1321 (1948).

Received March 6, 1958

* Original Russian pagination. See C.B. Translation.

COMPOUNDS WITH POTENTIAL ANTITUBERCULAR ACTIVITY

I. THIOAMIDES OF CERTAIN THIAZOLECARBOXYLIC ACIDS

T. P. Sycheva and I. V. Lebedeva

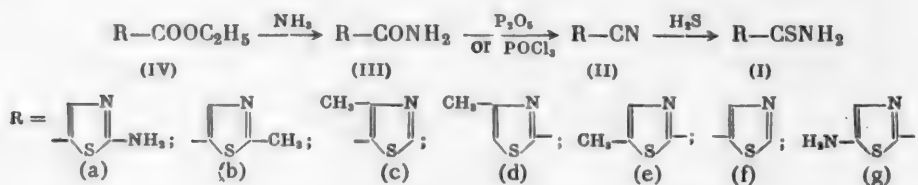
S. Ordzhonikidze All-Union Chemicopharmaceutical Scientific Research Institute

In recent years, thioamides of various heterocyclic acids [1, 2] have begun to attract attention as compounds with potential antitubercular action. Preparations with very high chemotherapeutic activity were found [2] amongst the thioamides of pyridinecarboxylic acids, in particular, α -alkylisonicotinic acid.

It was completely unexpected that the introduction of an alkyl radical into the α -position of the pyridine nucleus not only did not lower the activity of the thioamide of isonicotinic acid (as was noted with derivatives of isonicotinoylhydrazine), but on the contrary, sharply increased it. In connection with this it seemed interesting to prepare a series of thioamides of thiazolecarboxylic acids and also the corresponding methyl-substituted derivatives and to investigate their antibacterial action. The thioamides of 2-thiazolecarboxylic [3, 4], 4-thiazolecarboxylic [4] and 5-thiazolecarboxylic [5] acids and also the thioamide of 5-amino-2-thiazolecarboxylic acid (Chrysean) [6] are described in the literature. There is no information in the literature on the chemotherapeutic activity of these compounds.

To investigate their chemotherapeutic activity, we prepared the previously known thioamides of 5-amino-2-thiazolecarboxylic (1g) and 5-thiazolecarboxylic (1f) acids. Together with this, we synthesized a series of new thioamides, including the isomer of Chrysean, the thioamide of 2-amino-5-thiazolecarboxylic acid (1a) and also the thioamides of 2-methyl-5- (1b), 4-methyl-5- (1c), 4-methyl-2- (1d) and 5-methyl-2-thiazolecarboxylic (1e) acids.

For the preparation of these compounds we used the general method of synthesis according to the scheme:



Esters of thiazolecarboxylic acids (IV) were obtained by condensation of α -halocarboxylic acids with thiourea or the thioamides of the simplest acids, formic, acetic or oxalic acids. The action of an aqueous or alcoholic solution of ammonia on the esters gave satisfactory yields of the amides of the thiazolecarboxylic acids. The latter were converted into nitriles by dehydration by two methods: for amides with m. p. below 160°, phosphorus pentoxide was used and for those with higher melting points, phosphorus oxychloride. Performing the reaction with phosphorus oxychloride in pyridine [7] did not give a better yield.

For conversion of the amide of 2-amino-5-thiazolecarboxylic acid into the corresponding nitrile, the amino group was first acetylated and then the acetyl derivative obtained was treated with phosphorus oxychloride. The nitrile of 2-acetamino-5-thiazolecarboxylic acid was converted into the thioamide and then the acetyl group hydrolyzed. Attempts to prepare the nitrile of 2-acetamino-5-thiazolecarboxylic acid from

2-aminothiazole via the appropriate bromide by replacement of the bromine by the cyano group [8] were unsuccessful. In order to prepare the dithioamide of 4,5-thiazoledicarboxylic acid, the dinitrile of this acid was synthesized. However, it was not possible to convert it into the thioamide: during treatment with hydrogen sulfide, both in alcohol solution in the presence of ammonia and in benzene in the presence of diethylamine, there was strong tar formation and the liberation of sulfur.

All the thioamides obtained and also certain of the intermediate compounds, amides and nitriles, were tested chemotherapeutically. No preparations showing antibacterial action were found among them. *

EXPERIMENTAL

1. Thioamide of 5-thiazolecarboxylic acid (If). A solution of 1.47 g of the nitrile of 5-thiazolecarboxylic acid [5] (If) in 15 ml of a 30% methanol solution of ammonia was saturated with dry hydrogen chloride at 15-20°. After half an hour, a yellow precipitate formed. The reaction mixture was left for 15 hours at room temperature, then 15 ml of water was added and the crystals collected by filtration. Recrystallization from water yielded 1.75 g (91.2%) of thioamide with m. p. 142°-143° (literature data [5]; 139-140°).

2. Amide of 2-acetamino-5-thiazolecarboxylic acid. To 45 ml of acetic acid and 22.5 ml of acetic anhydride was added 4.2 g of the amide of 2-amino-5-thiazolecarboxylic acid (IIIa) and the mixture heated with stirring until the amide dissolved. Soon after solution, a precipitate formed and this was collected after an hour and recrystallized from acetic acid. We obtained 4 g of a substance with m. p. 326-326.5°.

Found %: C 38.74; H 4.19; S 17.42. $C_6H_7O_2N_3S$. Calculated %: C 38.9; H 3.78; S 17.3.

3. Nitrile of 2-acetamino-5-thiazolecarboxylic acid. A mixture of 4 g of the amide of 2-acetamino-5-thiazolecarboxylic acid and 15 ml of phosphorus oxychloride was heated and stirred on an oil bath at 105-110° for 7 hours. The excess oxychloride was removed in vacuum and the residue treated with 5% bicarbonate with cooling. The liberated nitrile was collected, washed with water and recrystallized from alcohol. We obtained 2.35 g of a substance with decomp. p. 291-292° (literature data; 295° [8]).

4. Thioamide of 2-acetamino-5-thiazolecarboxylic acid. A solution of 2.35 g of the nitrile of 2-acetamino-5-thiazolecarboxylic acid in 25 ml of a 30% solution of ammonia in methanol was treated with dry hydrogen sulfide. The reaction was performed as in experiment 1. The thioamide obtained was recrystallized from dilute acetic acid. The yield was 2.35 g (83%). The m. p. was 269-270° (with decomp.).

Found %: C 35.58; H 3.56; N 20.68. $C_6H_7H_3OS_2$. Calculated %: C 35.8; H 3.43; N 20.89.

5. Thioamide of 2-amino-5-thiazolecarboxylic acid (Ia). A mixture of 2.35 g of the thioamide of 2-acetamino-5-thiazolecarboxylic acid in 25 ml of 0.5 N HCl solution was boiled for 5 hours. The cooled solution was neutralized with 10% sodium carbonate solution. The liberated crystals were collected and recrystallized from water. We obtained 1.5 g (80.6%) of substance with m. p. 217-218° (after drying in vacuum at 100°).

Found %: C 29.98; H 3.19; N 26.03. $C_4H_5N_3S_2$. Calculated %: C 30.02; H 3.14; N 26.4.

6. Amide of 2-methyl-5-thiazolecarboxylic acid (IIb). A mixture of 3.7 g of the ethyl ester of 2-methyl-5-thiazolecarboxylic acid [9] (IVb) and 25 ml of concentrated aqueous ammonia was shaken for 24 hours at room temperature. The precipitate was filtered off, washed with water and recrystallized from hot water. We obtained 2.24 g (72.9%) of a substance with m. p. 201-202°.

Found %: C 42.44; H 4.26; N 19.76. $C_5H_6ON_2S$. Calculated %: C 42.25; H 4.23; N 19.7.

7. Nitrile of 2-methyl-5-thiazolecarboxylic acid (IIb). In the reaction was used 2.24 g of the amide of 2-methyl-5-thiazolecarboxylic acid (IIb) and 20 ml of phosphorus oxychloride. The reaction was performed as in experiment 3. The nitrile, which was liberated in the form of an oil after neutralization, was extracted

*The work was performed in the Laboratory for the Synthesis of Antitubercular Compounds under the direction of M. N. Shchukina. The biological investigations were carried out in the Chemotherapy Department of the All-Union Chemicopharmaceutical Scientific Research Institute by S. N. Milovanova and T. N. Zyкова under the direction of G. N. Pershin.

with ether. After drying of the ether extracts, removal of the solvent and cooling, the substance crystallized. After recrystallization from petroleum ether, the nitrile (1.22 g) had m. p. 41-43°.

Found %: C 48.38; H 3.26; S 25.69. $C_5H_4N_2S$. Calculated %: C 48.35; H 3.23; S 25.8.

8. Thioamide of 2-methyl-5-thiazolecarboxylic acid (Ib). A solution of 1.22 g of the nitrile of 2-methyl-5-thiazolecarboxylic acid (IIb) in 20 ml of a 30% solution of ammonia in methanol was saturated with dry hydrogen sulfide. The reaction was performed as in experiment 1. Recrystallization from water yielded 1 g of thioamide with m. p. 191-193°.

Found %: C 38.30; H 3.71; S 40.32. $C_5H_6N_2S_2$. Calculated %: C 37.90; H 3.79; S 40.5.

9. Thioamide of 4-methyl-5-thiazolecarboxylic acid (Ic). A solution of 1 g of the nitrile of 4-methyl-5-thiazolecarboxylic acid [10] (IIc) in 15 ml of a 30% solution of ammonia in methyl alcohol was saturated in dry hydrogen sulfide. The reaction was as in experiment 1. Recrystallization from water yielded 0.8 g of thioamide with m. p. 163-164°.

Found %: C 37.83; H 3.98. $C_5H_6N_2S_2$. Calculated %: C 37.9; H 3.79.

10. Nitrile of 4-methyl-2-thiazolecarboxylic acid (IId). A mixture of 3 g of finely ground amide of 4-methyl-2-thiazolecarboxylic acid [11] (IIId) with 3.7 g of phosphorus pentoxide was heated in a vacuum of 24-25 mm at 160-170° for an hour. After cooling, the reaction mass was dissolved in 15-20 ml of warm water and the solution neutralized with 10% sodium carbonate solution. The liberated oil was extracted with ether. The ether solution was dried, the solvent removed and the residue recrystallized from petroleum ether. The weight of the product was 1.1 g and the m. p. 40-42°.

Found %: C 48.26; H 3.46; S 25.66. $C_5H_4N_2S$. Calculated %: C 48.35; H 3.32; S 25.8.

11. Thioamide of 4-methyl-2-thiazolecarboxylic acid (Id). The reaction was as in experiment 1. From 1 g of the nitrile of 4-methyl-2-thiazolecarboxylic acid (IId) we obtained 1.15 g (90%) of the thioamide. After recrystallization from 50% alcohol, the substance had m. p. 160-161°.

Found %: C 37.90; H 3.89; N 17.44. $C_5H_6N_2S_2$. Calculated %: C 37.90; H 3.79; N 17.7.

12. Amide of 5-methyl-2-thiazolecarboxylic acid (IIIf). The reaction was performed as in experiment 6. From 6.5 g of the ethyl ester of 5-methyl-2-thiazolecarboxylic acid [12] (IVe) we obtained 3.7 g (68.5%) of amide with m. p. 197.5-198.5° after recrystallization from alcohol.

Found %: C 42.31; H 4.28; N 19.7. $C_5H_6ON_2S$. Calculated %: C 42.25; H 4.22; N 19.17.

13. Nitrile of 5-methyl-2-thiazolecarboxylic acid (IIe). The reaction was performed with phosphorus oxychloride as in experiment 3. From 2 g of the amide of 5-methyl-2-thiazolecarboxylic acid (IIe) we obtained 0.6 g of the thioamide. After recrystallization from alcohol, the substance had m. p. 201.5-202.5°.

Found %: C 48.26; H 3.28; S 26.03. $C_5H_4N_2S$. Calculated %: C 48.4; H 3.22; S 25.8.

14. Thioamide of 5-methyl-2-thiazolecarboxylic acid (Ie). The reaction was as in experiment 1. From 0.5 g of the nitrile of 5-methyl-2-thiazolecarboxylic acid (IIe) we obtained 0.6 g of the thioamide. After recrystallization from alcohol, the substance had m. p. 201.5-202.5°.

Found %: C 37.9; H 3.7; S 40.29. $C_5H_6N_2S_2$. Calculated %: C 38.0; H 3.9; S 40.5

15. The nitrile of 4,5-thiazoledicarboxylic acid. The reaction was performed with phosphorus oxychloride as in experiment 3. From 4.5 g of the diamide of 4,5-thiazoledicarboxylic acid [13] we obtained 2.84 g of the dinitrile, which had m. p. 69-70° after recrystallization from ether.

Found %: C 44.20; H 0.86; N 31.15. C_5HN_2S . Calculated %: C 44.5; H 0.74; N 31.1.

SUMMARY

A series of thioamides of thiazolecarboxylic acids, which are not described in the literature, were obtained and also some of their derivatives.

LITERATURE CITED

- [1] Th. Gardner, E. Wenis, and J. Lee, *J. Org. Ch.*, 19, 735 (1954); 22, 984 (1957); M. Meltzer, A. Lewis, and J. Ring, *J. Am. Chem. Soc.* 77, 4062 (1955); F. P. Doyle, W. Ferrier, D. O. Holland, et al., *J. Chem. Soc.* 1956, 2853.
- [2] D. Libermann, N. Rist, F. Grumbach, and S. Cals, *Bull. Soc. Chim. Biol.* 1957, 1195.
- [3] D. D. Libman and R. Slack, *J. Chem. Soc.* 1956, 2253.
- [4] R. Menasse, B. Prijs, and H. Erlenmeyer, *Helv. Chim. Acta*, 40, 554 (1957).
- [5] W. Traupel, M. Erue, and E. Sorkun, *Helv. Chim. Acta*, 33, 1960 (1950).
- [6] M. H. Arnold and C. W. Scaife, *J. Chem. Soc.*, 1944, 103.
- [7] R. Delaby, G. Tsatsas, and X. Lusinchi, *C.r.*, 242, 2644 (1956).
- [8] H. J. Backer and J. A. R. Buisman, *Rec. trav. chim.*, 63, 226 (1944).
- [9] A. Schoberl and M. Stock, *Ber.* 73, 1240 (1940).
- [10] C. R. Harington, and R. C. G. Moggridge, *J. Chem. Soc.*, 1939, 443.
- [11] H. Schenkel, E. Marbet, and H. Erlenmeyer, *Helv. Chim. Acta*, 27, 1437 (1944).
- [12] H. Erlenmeyer and P. Schmidt, *Helv. Chem. Acta*, 29, 1957 (1946).
- [13] S. J. Childress, and R. J. Mc Ree, *J. Am. Chem. Soc.* 73, 3862 (1951).

Received February 6, 1958

SYNTHESIS OF ORGANOPHOSPHORUS COMPOUNDS FROM HYDROCARBONS AND THEIR DERIVATIVES

X. OXIDATIVE CHLOROPHOSPHINATION OF CERTAIN ETHYLENE DERIVATIVES

L. Z. Soborovskii, Yu. M. Zinov'ev and T. G. Spiridonova

It was previously shown that the oxidative chlorophosphination of olefins and chloroolefins yielded acid chlorides of the corresponding chloro- and dichloroalkanephosphinic acids [1, 2]. A description was recently given of the oxidative chlorophosphination of methyl acrylate [3].

In the present work we established the possibility of oxidative chlorophosphination of ethylene derivatives containing bromine, chlorine, fluorine and such a comparatively complicated group as a sulfonyl fluoride radical. We carried out the oxidative chlorophosphination of 1,2-dichloroethylene, vinyl bromide, vinyl fluoride, 1,2-fluorochloroethylene and vinylsulfonyl fluoride and obtained the acid chlorides of the corresponding substituted alkylphosphinic acids. As is known, the oxidative chlorophosphination of vinyl chloride leads to the formation of isomeric substances, differing in the relative position of the chlorine and the POCl_2 residue [2].

The acid chlorides obtained in the present work were also apparently a mixture of two isomers of the structure $\text{CH}_2\text{ClCHX}(\text{O})\text{Cl}_2$ and $\text{CHClXCH}_2(\text{O})\text{Cl}_2$. In particular, for the reaction product of vinyl fluoride, phosphorus trichloride and oxygen, experimental proof of the existence of isomers was obtained (the problem of separating the isomeric compounds formed is the subject of a separate communication).

Fractionation of the product of oxidative chlorophosphination of vinyl bromide yielded two fractions which differed not only in boiling point but also in composition. The lower fraction was found to be the acid chloride of bromovinylphosphinic acid and the higher one, the acid chloride of chlorobromoethanephosphinic acid. The former compound apparently was produced as a result of the secondary reaction of dehydrochlorination of the acid chloride of chlorobromoethanephosphinic acid during the distillation.

Previously we showed that with the acid chloride of dichloroethanephosphinic acid, elimination of hydrogen halide occurred predominantly from the 2,2-substituted derivative [2]. Therefore, with a sufficient degree of probability it may be assumed that the lower-boiling substance was the 2-bromosubstituted derivative and the higher-boiling one, the 1-chloro-2-bromo derivative, i.e., the structures of the compounds isolated correspond to the formulas $\text{BrCH}=\text{CHP}(\text{O})\text{Cl}_2$ and $\text{CH}_2\text{BrCHClP}(\text{O})\text{Cl}_2$. The properties of the acid chlorides synthesized are presented in the table.

Attempts to carry out the oxidative chlorophosphination of vinylidene chloride, trichloroethylene and tetrachloroethylene were unsuccessful. The first compound polymerized and the two latter ones were recovered from the reaction unchanged.

In addition, during the present work the previously described 1,2-dichlorobromoethane was obtained by the action of chlorine on vinyl bromide.

EXPERIMENTAL

Oxidative chlorophosphination of 1,2-dichloroethylene. Oxygen was passed through a mixture of 20.0 g (0.21 mole) of 1,2-dichloroethylene (b. p. 50-54°) and 400 g (3 moles) of phosphorus trichloride at 0° until reaction ceased. From the reaction mixture we isolated 18.8 g (40%) of a substance which was slowly hydrolyzed by water.

Found % C 10.81, 10.60; H 0.60, 0.70; P 12.63, 12.52. $C_2H_2OCl_2P$. Calculated % C 9.59; H 0.80; P 12.37.

Oxidative chlorophosphination of vinyl bromide. Oxygen was passed through a mixture of 34.0 g (0.32 mole) of vinyl bromide (b. p. 16°), obtained by the dehydrobromination of 1,2-dibromoethane, and 400 g (2.9 moles) of phosphorus trichloride until reaction ceased. After removal of the low-boiling fraction (70° , 200 mm), the residue was distilled. At $95-125^\circ$ (0.05 mm), 24.2 g (29.2%) of substance distilled. A second distillation (3 mm) yielded the following fractions up to 85° - 0.9 g, $81-82^\circ$ - 8.0 g, $82-98^\circ$ - 0.65 g, $99-100^\circ$ - 4.8 g, $101-110^\circ$ - 3.7 g.

Analysis of fraction $81-82^\circ$ (3 mm): d_4^{20} 1.7415, n_D^{20} 1.4889. MR_D 37.12; calc. 36.79.

Found % P 13.06, 12.83. $C_2H_2BrCl_2OP$. Calculated % P 13.83.

Analysis of fraction $99-100^\circ$ (3 mm): d_4^{20} 1.9720, n_D^{20} 1.5378, MR_D 41.28; calc. 42.12.

Found % Cl (hydr.) 27.71; P 11.49, 11.31. $C_2H_2BrCl_2OP$. Calculated % Cl (hydr.) 27.25, P 11.90.

Starting ethylene derivatives	Formula of acid chloride obtained	Yield (in %)	B. p. at 3 mm	d_4^{20}	n_D^{20}	MR_D	
						found	calc.
$CHCl=CHCl$	$CHCl_2CHClP(O)Cl_2$	40.0	$89-92^\circ$	1.7172	1.4990	—	—
$CH_2=CHBr$	$CH_2BrCHClP(O)Cl_2$	29.2	$99-100^\circ$	1.9720	1.5378	41.28	42.12
$CH_2=CHF$	$C_2H_3FCIP(O)Cl_2^*$	6.3	109^{**}	1.6531	1.4715	33.78	34.33
$CHF=CHCl$	$C_2H_2FCl_2P(O)Cl_2^*$	25.2	$66-70^\circ$	1.6893	1.4640	38.0	39.19
$CH_2=CHSO_2F$	$(FSO_2)C_2H_3ClP(O)Cl_2$	9.3	$95-97^\circ$	1.7264	1.4618	42.11	42.96
$CH_2=CHBr$	$CHBr=CHP(O)Cl_2$	—	$81-82^\circ$	1.7415	1.4889	37.12	36.79

* The substance could be a mixture of isomers.

** At 30 mm.

Oxidative chlorophosphination of vinyl fluoride. 15 liters of sulfuric acid dried vinyl fluoride was passed from a gasometer into phosphorus trichloride (275 g, 2 moles), cooled to -70° . Oxygen was passed through the mixture obtained at -70° until the mass crystallized. We isolated 7.6 g (6.3%) of material.

Found % Cl (hydr.) 35.8, 35.6; P 15.60, 15.57. $C_2H_2OFCl_2P$. Calculated % Cl (hydr.) 35.56; P 15.53.

Oxidative chlorophosphination of 1,2-fluorochloroethylene. Oxygen was passed through a mixture of 16.0 g (0.2 mole) of 1,2-fluorochloroethylene [4] and 300 g (2.2 mole) of phosphorus trichloride at -5° until reaction ceased. From the reaction mixture we isolated 11.7 g (25.2%) of a substance.

Found % C 10.00, 10.30; H 1.02, 0.93; P 12.96, 12.78. $C_2H_2OFCl_2P$. Calculated % C 10.36; H 0.87; P 13.36.

Oxidative chlorophosphination of vinylsulfonyl fluoride. Oxygen was passed through a mixture of 60 g (0.55 mole) of vinylsulfonyl fluoride [5] and 400 g (2.90 mole) of phosphorus trichloride at $20-25^\circ$ until reaction ceased. A fraction was isolated boiling at $80-110^\circ$ (10 mm). We obtained 13.5 g (9.3%) of the substance. The constants were determined after a second distillation.

Found % F 6.18, 6.64; P 12.26, 12.13. $C_2H_2O_2Cl_2FPS$. Calculated % F 7.21; P 11.75.

Preparation of 1,2-dichloro-1-bromoethane. Chlorine was passed into a solution of 37.7 g of vinyl bromide in 200 ml of carbon tetrachloride at 0.5° until a color appeared. The solvent was then distilled from the reaction mixture and the residue yielded a fraction of 32.6 g (52%), which distilled at $134-137^\circ$. The constants were determined after a second distillation:

b. p. $134-135^\circ$ (750 mm), d_4^{20} 1.8662, n_D^{20} 1.5136. MR_D 28.60; calc. 28.93.

Found % C 13.81, 13.34; H 1.61, 2.13. $C_2H_2BrCl_2$. Calculated % C 13.50; H 1.67.

SUMMARY

1. The oxidative chlorophosphination of five ethylene derivatives was accomplished.
2. The acid chlorides of 1-chloro-2-bromo-, 1,2,2-trichloro-, fluorochloro-, fluorodichloro- and chloro-(fluorosulfonyl)-ethanephosphinic acid and the acid chloride of 2-bromoethenephosphinic acid were synthesized.
3. 1,2-Dichlorobromoethane, which has not been described up to now, was prepared.

LITERATURE CITED

- [1] L. Z. Soborovskii, Yu. M. Zinov'ev and M. A. Énglin, *Proc. Acad. Sci. USSR*, 67, 293 (1949).
- [2] L. Z. Soborovskii, Yu. M. Zinov'ev and L. I. Muler, *Proc. Acad. Sci. USSR*, 109, 98 (1956).*
- [3] A. Ya. Yakubovich, L. Z. Soborovskii, L. I. Muler and V. S. Faermark, *J. Gen. Chem.* 28, 317 (1958).*
- [4] U. S. Pat. 2,337,297; Ch. A. 39, 4081 (1945).
- [5] L. Z. Soborovskii, B. M. Gladshtein, V. N. Chernetskii and M. L. Kiseleva, *J. Gen. Chem.*, 28, 1870 (1958).*

Received March 3, 1958

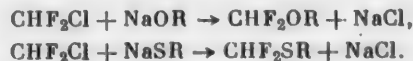
*Original Russian pagination. See C.B. Translation.

DIFLUOROCHLOROMETHANE AS A DIFLUOROMETHYLATING AGENT

I. REACTION OF DIFLUOROCHLOROMETHANE WITH SODIUM ALCOHOLATES AND MERCAPTIDES

L. Z. Soborovskii and N. F. Baina

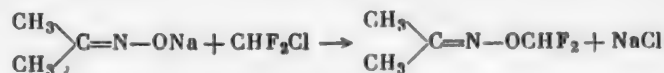
Although difluorochloromethane (Freon-22) was prepared as early as 1931 [1], its chemical properties have been studied very little up to now. Investigations have only been made on the pyrolytic conversion of difluorochloromethane to tetrafluoroethylene [2] and the formation of fluoroform by the action of aluminum trichloride on difluorochloromethane in the cold [3]. It is accepted that freons, including difluorochloromethane, are extremely chemically inert substances. Despite this, we established that the chlorine atom in the difluorochloromethane molecule is comparatively labile. It was found that at room temperature difluorochloromethane reacted with sodium alcoholates and mercaptides in an anhydrous alcohol medium with the formation of fluorinated ethers and fluorinated sulfides by the scheme:



These reactions proceeded very readily, even when difluorochloromethane was passed through alcohol solutions of sodium alcoholates. Methyl difluoromethyl and *n*-butyl difluoromethyl ethers were obtained in this way. The reaction of sodium β -hydroxyethyl mercaptide with difluorochloromethane in an ethyl alcohol medium gave a good yield of the previously unknown β -hydroxyethyl difluoromethyl sulfide.



Under the reaction conditions described for the preparation of unsubstituted oxime ethers [4], the reaction of difluorochloromethane with the sodio derivative of acetoxime gave a small yield of the previously unknown difluoromethyl ether of acetoxime.



EXPERIMENTAL

1. Methyl difluoromethyl ether ($\text{CH}_3-\text{O}-\text{CHF}_2$). 9.2 g of metallic sodium was dissolved with stirring in 80 ml of dry methanol. Then 40 g of difluorochloromethane was passed through the alcoholate solution as a moderate stream with stirring over a period of 5 hours. When the Freon-22 was passed in, the mixture heated up to 60° and a precipitate of NaCl formed. At the end of the reaction, 11.0 g of liquid had collected in a trap cooled with solid carbon dioxide. Distillation of this liquid on an efficient fractionating column (about 100 theoretical plates) yielded 7.2 g of methyl fluoromethyl ether with b. p. -5 to -4°. The yield was 23 %.

Found %: C 29.73; H 4.15; F 45.58. M 81.2. $\text{C}_2\text{H}_4\text{OF}_2$. Calculated %: C 29.27; H 4.88; F 46.34. M 82.0.

2. n-Butyl difluoromethyl ether ($n\text{-C}_4\text{H}_9\text{OCHF}_2$). 5.75 g of metallic sodium was dissolved in 111 g of n-butyl alcohol. Then over a period of 2 hours, 30.8 g of difluorochloromethane was passed into the warm solution of sodium n-butyrate. The reaction mixture was heated at 70–80° for an hour and filtered free from precipitate. The solvent was distilled from the filtrate and the residue fractionated at normal pressure. We obtained 3.7 g of ether in the form of a clear, mobile liquid with an ether smell.

B. p. 67–68°, d_4^{20} 0.9643, n_D^{20} 1.3465, M_R 27.3; calc. 26.83.

Found %: C 48.81; H 9.32; F 30.37. $\text{C}_6\text{H}_{10}\text{OF}_2$. Calculated %: C 48.40; H 8.06; F 30.64.

3. β -Hydroxyethyl difluoromethyl sulfide ($\text{HOCH}_2\text{CH}_2\text{SCHF}_2$). 8.9 g of β -hydroxyethyl mercaptan was added with stirring to 2.7 g of metallic sodium in 150 ml of anhydrous alcohol. With stirring at normal temperature, excess difluorochloromethane was passed through the solution obtained for a period of one hour, and 25 g of gas was absorbed. Sodium chloride precipitated from the solution. After 20 hours, the precipitate was removed by filtration and the filtrate fractionated. After removal of the ethanol, the residue yielded 8.7 g (60%) of sulfide.

B. p. 51–52° at 3 mm, d_4^{20} 1.3306, n_D^{20} 1.4402. M_R 25.37; calc. 25.47.

Found %: C 28.95; H 4.90; S 25.47. $\text{C}_4\text{H}_8\text{OSF}_2$. Calculated %: C 28.12; H 4.69; S 25.00.

4. Difluoromethyl ether of acetoxime $\text{CHF}_2\text{ON} = \text{C}(\text{CH}_3)_2$. In a reactor fitted with a mechanical stirrer, a reflux condenser, a thermometer and a difluorochloromethane inlet tube was dissolved 9.5 g of metallic sodium in 14 ml of anhydrous methanol. Then 300 ml of absolute ether and 50 g of acetoxime were introduced into the flask. Over a period of 3 hours, 55 g of difluorochloromethane was passed into the reaction mixture at room temperature. The mixture was left overnight. The precipitate was then separated. The filtrate was dried with CaCl_2 , saturated with HCl and the precipitated acetoxime hydrochloride separated. The ether solution was washed with sodium carbonate solution, dried over CaCl_2 and fractionated. After removal of the ether, the residue yielded 2.4 g of the acetoxime ether. The clear, mobile liquid was insoluble in water.

B. p. 90–92°, d_4^{20} 1.0609, n_D^{20} 1.3730, M_R 26.23; calc. 26.33.

Found %: N 11.38; F 30.11. $\text{C}_4\text{H}_7\text{ONF}_2$. Calculated %: N 11.38; F 30.89.

SUMMARY

1. It was established that the atom of chlorine in difluorochloromethane is relatively labile and as a result, difluorochloromethane may be used as a difluoromethylating agent.

2. The reaction of difluorochloromethane with sodium alcoholates and mercaptides and also with the sodio derivative of acetoxime yielded the previously unknown fluorinated ethers, methyl and n-butyl difluoromethyl ethers, β -hydroxyethyl difluoromethyl sulfide and the difluoromethyl ether of acetoxime.

LITERATURE CITED

- [1] French Pat. 701324; Zbl. 1931, II, 120.
- [2] J. D. Park, A. F. Benning, F. B. Downing, J. E. Laucius, and R. C. Mc Harness, Ind. Eng. Ch. 39, 354 (1947).
- [3] U. S. Pat. 2,426,638; Ch. A. 42, 199 (1948).
- [4] A. N. Nesmeyanov, A. K. Kochetkov and R. Kh. Freidlina, Bull. Acad. Sci. USSR, 1951, 512.

Received March 6, 1958.

* Prepared by O. I. Bolakova.

DIFLUOROCHLOROMETHANE AS A DIFLUOROMETHYLATING AGENT

II. REACTION OF DIFLUOROCHLOROMETHANE WITH SODIUM DIALKYLPHOSPHITES

L. Z. Soborovskii and N. F. Baina

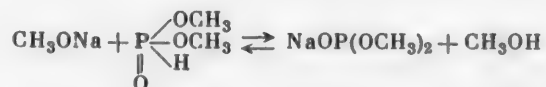
Up to the present time, only a few derivatives of fluorinated alkylphosphinic acids have been known; the difluorobutyl ester of fluoromethylphosphinic acid and the diethyl ester of β -fluoroethylphosphinic acid were prepared for the first time by Saunders et al. in 1948 [1] and trifluoromethylphosphinic acid was described by Haszeldine in 1954 [2]. Previously we showed that due to the relative lability of the chlorine atom in the difluorochloromethane molecule, the latter readily alkylated alcoholates, mercaptides and other compounds [3].

In the present work a study was made of the possibility of using difluorochloromethane in the Michaelis-Becker reaction with sodium derivatives of dialkylphosphorous acids so as to prepare the corresponding esters of difluoromethylphosphinic acid. It was established that difluorochloromethane reacted with sodium derivatives of dialkylphosphorous acids in an inert solvent to form esters of difluoromethylphosphinic acid.



This reaction proceeded most readily with sodium derivatives of higher dialkylphosphorous acids, in particular, with the dibutylphosphite, which is known to be readily soluble in liquid hydrocarbons [4]. Thus, for example, passing difluorochloromethane into a benzene solution of sodium dibutylphosphite gave up to 70% yield of the dibutyl ester of difluoromethylphosphinic acid. By this method we also prepared the dimethyl, diethyl and diisopropyl esters of difluoromethylphosphinic acid.

It should be noted that when the reaction of difluorochloromethane with sodium dimethylphosphite was performed in an alcohol medium, instead of the expected dimethyl ester of difluoromethylphosphinic acid, the main reaction product isolated was dimethyl phosphite together with a very small amount of the desired ester. The reason for this anomalous reaction was as follows; the sodium methylate-dimethyl phosphite system in methanol solution is in equilibrium with sodium dimethylphosphite and methanol.



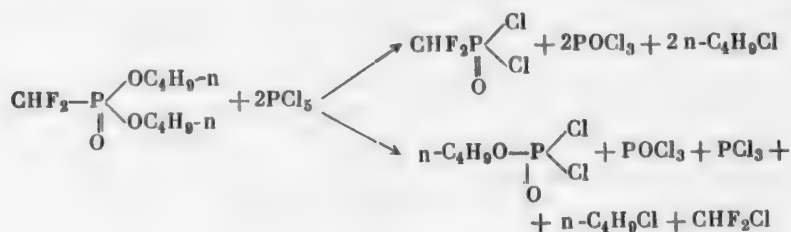
Under normal conditions, this equilibrium is displaced to the right; when difluorochloromethane is passed through the mixture, the facile reaction of the latter with sodium methylate begins and is accompanied by the separation of sodium chloride.



As a result of this, the equilibrium is displaced towards the formation of free dimethyl phosphite, which appears as the main reaction product. Simultaneously, but at a lower rate, difluorochloromethane reacts with sodium dimethylphosphite, leading to the formation of a small amount of the dimethyl ester of difluoromethylphosphinic acid.

Treatment of the dibutyl ester of the difluoromethylphosphinic acid obtained with phosphorus pentachloride under mild conditions (insufficient PCl_5 and a temperature of about 70°) gave a small yield (30%) of the previously unknown diacid chloride of difluoromethylphosphinic acid. When the reaction was performed under more drastic conditions (heating equimolecular amounts of the reagents together), rupture of the phosphorus-carbon bond occurred and the main product isolated was the diacid chloride of butylphosphoric acid with b. p. $89-90^\circ$ at 17 mm, identical with butyl dichlorophosphate described by Gerrard [5].

Phosphorus pentachloride reacted similarly with the diethyl ester of difluoromethylphosphinic acid under these conditions; this yielded ethyl dichlorophosphate with b. p. 65-67° at 17 mm and an insignificant amount of the expected diacid chloride of difluoromethylphosphinic acid. The appearance of considerable amounts of alkyl dichlorophosphates in this reaction indicates that together with the normal replacement of alkoxy by chlorine, there is also a side reaction accompanied by rupture of the phosphorus-carbon bond.



EXPERIMENTAL

Diethyl ester of difluoromethylphosphinic acid. 52 g of difluorochloromethane was passed at a moderate rate into a solution of sodium diethylphosphite in petroleum ether (from 11.5 g of metallic sodium and 69.0 g of diethyl phosphite at 30-35° with stirring. Sodium chloride precipitated from the reaction mixture. The mixture was left overnight. After removal of the precipitate and evaporation of the petroleum ether, the residue was vacuum distilled. We obtained 45.6 g (48.6%) of ester.

The clear, colorless liquid was soluble in water and organic solvents.

B. p. 85.6-86.5 at 12 mm, d², 1.1934.

Found %: C 32.70; H 6.33; P 16.54; F 19.86. $C_8H_{11}O_3PF_2$. Calculated %: C 31.92; H 5.85; P 16.49; F 20.21.

The other esters of difluoromethylphosphinic acid were obtained by the same method.

Diisopropyl ester of difluoromethylphosphinic acid. 3.68 g of finely divided sodium metal, 26.6 g of diisopropyl phosphite, 450 ml of petroleum ether and 30 g of difluorochloromethane were used. We obtained 16.4 g (48.5%) of ester.

B. p. 89-90° at 12 mm, d_4^{20} 1.1153, n_D^{20} 1.3870, MR_D 45.61; calc. 45.21.

Found %: C 39.48; H 6.41; P 14.60; F 16.81. $C_7H_{15}O_3PF_2$. Calculated %: C 38.90; H 6.94; P 14.35; F 17.59.

Dibutyl ester of methylfluorophosphinic acid. 12.4 g of metallic sodium, 800 ml of benzene (b. p. 60-100°), 105 g of dibutyl phosphite (b. p. 117° at 2 mm) and 60 g of difluorochloromethane were used. The reaction mixture was kept at room temperature for 48 hours. In this reaction, sodium chloride was not liberated immediately after difluorochloromethane was passed in, but only separated from the reaction mixture after a small amount of water had been added. We obtained 89 g (67.3%) of ester. The clear liquid was insoluble in water, but dissolved readily in organic solvents.

B. p. 124-125° at 12 mm, d^{20}_D 1.0913, n^{20}_D 1.4084.

Found %: C 44.76; H 7.28; P 13.61; F 15.31; C_4H_9O 58.61. $C_9H_{13}O_3PF_2$. Calculated %: C 44.26; H 7.79; P 13.72; F 15.57; C_4H_9O 59.0.

Reaction of dibutyl ester of difluoromethylphosphinic acid with phosphorus pentachloride. Into a flask fitted with a reflux condenser was placed 15 g of the dibutyl ester of difluoromethylphosphinic acid and 25 g of phosphorus pentachloride added in small portions over a period of 1.5 hours, while the temperature of the mixture was kept at about 70°. During the heating, a small amount of gas was evolved and this was condensed in a trap cooled with carbon dioxide. Three fractions were isolated from the reaction mixture: the 1st had b. p. 76-78° (11.3 g) and was a mixture of phosphorus trichloride and butyl chloride (found: 10.0% P^{III}, which represents 44.5% PCl₃); the 2nd with b. p. 100-105° (3.0 g) was phosphorus oxychloride; the 3rd with b. p. 50-52° at 50 mm (3.0 g) was the diacid chloride of difluoromethylphosphinic acid.

Found %: F 22.25; Cl 41.3. CHOPF₂Cl₂. Calculated %: F 22.48; Cl 42.0.

The undistillable residue represented about 50% by weight.

SUMMARY

1. The reaction of difluorochloromethane with sodium derivatives of dialkylphosphorous acids was accomplished. The previously unknown diethyl, diisopropyl and dibutyl esters of difluoromethylphosphinic acid were obtained and characterized.
2. The reaction of the dibutyl ester of difluoromethylphosphinic acid with phosphorus pentachloride gave the previously unknown diacid chloride of difluoromethylphosphinic acid.
3. It was found that during the action of PCl₅ on esters of difluoromethylphosphinic acid, together with the formation of the diacid chloride of difluoromethylphosphinic acid, there also occurred rupture of the phosphorus-carbon bond and the corresponding alkyl phosphates were formed.

LITERATURE CITED

- [1] B. C. Saunders, G. J. Stacey, F. Wild, and J. G. E. Wilding, J. Chem. Soc., 1948, 699.
- [2] F. W. Bennett, H. J. Emeleus, and R. N. Haszeldine, J. Chem. Soc., 1954, 3588, 3896; 1955, 563.
- [3] L. Z. Soborovskii and N. F. Baina, J. Gen. Chem., 29, 1132 (1959).*
- [4] G. M. Kosolapoff, J. Am. Chem. Soc. 69, 1002 (1947).
- [5] W. Gerrard, J. Chem. Soc., 1949, 1465.

Received March 6, 1958

* Original Russian pagination. See C.B. Translation.

THE REFORMATSKY REACTION WITH α -HALONITRILES

III. CONDENSATION OF METHOXYBENZALDEHYDES WITH BROMOACETONITRILE

N. S. Vul'fson and L. Kh. Vinograd

Scientific Research Institute of Organic Intermediates and Dyes

The condensation of benzaldehyde and chlorobenzaldehydes with bromoacetonitrile was described previously [1, 2]. Subsequently we have studied the condensation of bromoacetonitrile with *o*-, *m*- and *p*-methoxy- and 3,4-dimethoxybenzaldehydes under the normal conditions of the Reformatsky reaction. As with chlorobenzaldehyde and unsubstituted benzaldehyde, from *o*- and *m*-methoxybenzaldehydes we obtained the previously undescribed β -(2-methoxyphenyl)- and β -(3-methoxyphenyl)- β -hydroxypropionitriles; respectively. In the case of *p*-methoxy- and 3,4-dimethoxybenzaldehydes, we obtained the known nitriles of *p*-methoxy- and 3,4-dimethoxycinnamic acids [3,4]. By the action of hydrogen peroxide, β -(2-methoxyphenyl)- and β -(3-methoxyphenyl)- β -hydroxypropionitriles were converted into the amides of β -(2-methoxyphenyl)- and β -(3-methoxyphenyl)- β -hydroxypropionic acids and when hydrolyzed they formed 2- and 3-methoxycinnamic acids.

As in the condensation of *m*-chlorobenzaldehyde [2], the condensation of *m*-methoxybenzaldehyde gave a lower yield than in the case of the *o*- and *p*-isomers, while the use of mercuric chloride as a catalyst only raised the yield very slightly (from 22.1 to 25.7%). Very good results were obtained by replacing the normal solvents (a mixture of benzene and ether) by tetrahydrofuran [5]. The yields were thus raised from 49.7 to 70.4%, from 25.7 to 74%, from 34.6 to 62% and from 23 to 76.3% for *o*-, *m*- and *p*-methoxy and 3,4-dimethoxybenzaldehydes, respectively. The reaction proceeded extremely vigorously in tetrahydrofuran, making it possible to reduce its duration and decrease tar formation.

EXPERIMENTAL

Starting materials. *m*-Methoxybenzaldehyde was prepared by a known method [6] and had b. p. 72° (1 mm); *o*-methoxybenzaldehyde was prepared from salicylaldehyde by Baeyer's method [7] and had b. p. 86° (3 mm); *p*-methoxybenzaldehyde was distilled in a stream of nitrogen and had b. p. 80° (1 mm); 3,4-dimethoxybenzaldehyde was obtained from vanillin according to the data in [8] and had b. p. 112° (1 mm); tetrahydrofuran was prepared by heating butanediol-1,4 with 10% of concentrated sulfuric acid, drying the distillate obtained with sodium hydroxide and redistilling the product on a column; the yield was 90%, the b. p. 64-65° and the moisture content 0.017% (by volume); the zinc turnings (0.1-0.15 mm thick) were washed with acetone containing 2% of aqueous hydrochloric acid and then with pure acetone and dried under a drying lamp.

β -Hydroxy- β -(2-methoxyphenyl)-propionitrile. To 8 g of zinc, 0.3 g of mercuric chloride, and 13.6 g (0.1 mole) of *o*-methoxybenzaldehyde in 25 ml of tetrahydrofuran was added 2-3 drops of bromoacetonitrile and the mixture boiled for 5 minutes. A vigorous reaction began, the bath was removed and over a period of 7-10 minutes, 14.4 g (0.12 mole) of bromoacetonitrile was added with stirring. The reaction mixture was boiled for a further 1 hour, cooled slightly and a mixture of 75 g of crushed ice and 25 ml of glacial acetic acid added. The mixture was stirred for 30 minutes, 30 ml of benzene added, the liquid decanted from the unreacted zinc (0.5-1.0 g) and the organic layer separated and washed twice with 30 ml portions of water. The aqueous layer and washings were extracted with benzene and the extract added to the main mass. The solution was dried with magnesium sulfate, the solvent removed and the residue vacuum distilled in a stream

of nitrogen. The fraction with b. p. 159-162° (3 mm), weighing 12.45 g (70.4%), was β -hydroxy- β -(2-methoxyphenyl)-propionitrile. The colorless, viscous liquid crystallized when a seed was added. After recrystallization from CCl_4 and benzene, the substance melted at 77.5-78°. It was readily soluble in methanol, acetone and dioxane and insoluble in water.

Found %: C 67.52; H 6.15; N 7.85. $\text{C}_{10}\text{H}_{11}\text{O}_2\text{N}$. Calculated %: C 67.79; H 6.25; N 7.90.

Amide of β -hydroxy- β -(2-methoxyphenyl)-propionic acid. 0.4 g of β -hydroxy- β -(2-methoxyphenyl)-propionitrile, 2 ml of 30% hydrogen peroxide, 0.5 ml of 1 N sodium hydroxide solution and 0.5 ml of methanol were heated at 60-70° for 20 minutes. On cooling, a precipitate weighing 0.37 g (84%) formed. Recrystallization from 8 ml of water and 5 ml of dioxane yielded 0.15 g of amide with m. p. 184°.

Found %: C 61.11; H 6.54; N 7.30. $\text{C}_{10}\text{H}_{13}\text{O}_3\text{N}$. Calculated %: C 61.52; H 6.67; N 7.17.

2-Methoxycinnamic acid. 0.5 g of β -hydroxy- β -(2-methoxyphenyl)-propionitrile and 30 ml of 2 N potassium hydroxide solution were boiled together for 4 hours. Acidification yielded 0.3 g (59.7%) of the acid.

M. p. 177-178° (from methanol). The literature reports [9] m. p. 183°.

β -Hydroxy- β -(3-methoxyphenyl)-propionitrile was obtained similarly to the 2-isomer from m-methoxybenzaldehyde. The fraction with b. p. 164-168° (2 mm) weighing 13.1 g (74%), was a colorless, viscous liquid.

n_D^{20} 1.5460, d_4^{20} 1.2592, *

Found %: C 68.3; H 6.14; N 7.51. $\text{C}_{10}\text{H}_{11}\text{O}_2\text{N}$. Calculated %: C 67.78; H 6.25; N 7.90

Amide of β -hydroxy- β -(3-methoxyphenyl)-propionic acid. This was obtained similarly to the 2-isomer from β -hydroxy- β -(3-methoxyphenyl)-propionitrile; the yield was 76% and the m. p. 90.5° (from chloroform).

Found %: C 61.59; H 6.93; N 7.44. $\text{C}_{10}\text{H}_{13}\text{O}_3\text{N}$. Calculated %: C 61.52; H 6.67; N 7.47.

β -(p-Nitrobenzoyloxy)- β -(3-methoxyphenyl)-propionitrile. 0.3 g of β -hydroxy- β -(3-methoxyphenyl)-propionitrile, 0.32 g of p-nitrobenzoyl chloride and 1 ml of pyridine were boiled together for 5 minutes, cooled, filtered and washed with 1 N sodium hydroxide solution and water. The product was recrystallized from 20 ml of CCl_4 , then from 3 ml of methanol to yield 0.12 g of colorless crystals with m. p. 109-110°

Found %: C 62.60; H 4.43; N 8.25. $\text{C}_{17}\text{H}_{14}\text{O}_5\text{N}_2$. Calculated %: C 62.57; H 4.32; N 8.58.

3-Methoxycinnamic acid was obtained similarly to the 2-isomer from β -hydroxy- β -(3-methoxyphenyl)-propionitrile. The yield was 72.7% and the m. p. 118.5°. According to literature data [10]: m. p. 118 and 125°.

Nitrile of p-methoxycinnamic acid. This was obtained similar to β -hydroxy- β -(2-methoxyphenyl)-propionitrile from p-methoxybenzaldehyde. The fraction with b. p. 143-149° (4 mm), weighing 9.85 g (62%) was the nitrile. It had a sweet taste. After two recrystallizations from alcohol, the m. p. was 64°, which corresponds to literature data [3].

Found %: C 75.60; H 5.96; N 8.86. $\text{C}_{10}\text{H}_9\text{ON}$. Calculated %: C 75.45; H 5.66; N 8.80.

Nitrile of 3,4-dimethoxycinnamic acid. This material was obtained similarly to β -hydroxy- β -(2-methoxyphenyl)-propionitrile from 3,4-dimethoxybenzaldehyde. After the addition of the bromoacetonitrile, it was necessary to add 15 ml of tetrahydrofuran and 20 ml of benzene. The fraction with b. p. 172-178° (4 mm), weighing 14.37 g (76.3%), was the nitrile. The m. p. of 98° (from dilute alcohol) corresponded to literature data [4].

Found %: C 69.36; H 6.05; N 7.74. $\text{C}_{11}\text{H}_{11}\text{O}_2\text{N}$. Calculated %: C 69.82; H 5.86; N 7.44.

SUMMARY

1. A study was made of the condensation of o-, m- and p-methoxy- and 3,4-dimethoxybenzaldehydes with bromoacetonitrile under the conditions of the Reformatsky reaction.

2. o- and m-, β -hydroxy- β -(methoxyphenyl)-propionitriles and β -hydroxy- β -(methoxyphenyl)-propionamides were obtained and characterized.

* As in original - Publisher's note.

3. It was established that condensation in tetrahydrofuran made it possible to raise the yields of reaction products considerably.

LITERATURE CITED

- [1] N. S. Vul'fson and L. Kh. Vinograd, *Proc. Acad. Sci. USSR*, 106, 669 (1956).*
- [2] L. Kh. Vinograd and N. S. Vul'fson, *J. Gen. Chem.*, 28, 245 (1958).*
- [3] C. Curman and G. Estok, *J. Am. Chem. Soc.* 72, 4275 (1950).
- [4] E. Lorz, L. P. Albro, and R. Baltzli, *J. Am. Chem. Soc.*, 73, 483 (1951).
- [5] R. E. Miller and F. F. Nord, *J. Org. Chem. Soc.*, 15, 89 (1950).
- [6] *Synthetic Organic Preparations*, 4, 331 (1953).*
- [7] A. Baeyer and V. Villiger, *Ber.*, 35, 3023 (1902).
- [8] *Synthetic Organic Preparations*, 2, 142 (1949).
- [9] V. Prey and H. Berbalk, *Monatsh.* 82, 990 (1951).
- [10] L. Helfer, *Helv. Chim. Acta*, 7, 947 (1924); V. M. Rodionov and A. M. Fedorova, *Archiv. Pharmaz.*, 266, 116 (1928); *Zbl.*, 1928, I, 2251.

Received March 12, 1958

* Original Russian pagination. See C.B. Translation.

ORGANIC INSECTOFUNGICIDES

XXI. THE REACTION OF DIALKYL CHLOROTHIOPHOSPHATES AND PHOSPHORUS THIOTRICHORIDE WITH PHENOLS IN THE PRESENCE OF TERTIARY AMINES

Ya. A. Mandel'baum, N. N. Mel'nikov and Z. M. Bakanova

Scientific Institute of Fertilizers and Insectofungicides

One of the most common methods of preparing mixed esters of thiophosphoric acid is the reaction of dialkyl chlorothiophosphates with alkali phenolates of the appropriate phenols [1]. The reaction temperature may be lowered and its duration decreased by the use of tertiary amines [2, 3] or metallic copper and its salts [4] as catalysts. In addition, the reduction in reaction temperature in the preparation of mixed esters of thiophosphoric acid is of great practical interest since at low temperatures side reactions can be reduced to zero, especially the isomerization of thiophosphates reported by Plishchemuka [5].

In connection with the above we undertook a special investigation of the reactions of dialkyl chlorothiophosphates with phenols in the presence of certain tertiary amines. The first of these experiments showed that the reaction proceeded even at room temperature and gave good yields of the corresponding dialkyl aryl thiophosphates. The reaction proceeded readily in both hydrophilic and hydrophobic organic solvents and also without solvent. However, in the latter case the reaction mixture was difficult to stir due to the liberation of crystalline hydrochloride of the amine. Dialkyl aryl thiophosphates were obtained in good yields even from a reaction in alcohol solution. This indicates that the reaction with phenols proceeds many times more rapidly than that with alcohols.

There are two possible explanations of the mechanism of dialkyl aryl thiophosphate formation from dialkyl chlorothiophosphates and phenols in the presence of tertiary amines: 1) the reaction proceeds through the intermediate formation of a quaternary ammonium salt from the dialkyl chlorothiophosphate and the amine [2]; 2) there is an exchange reaction between the amine phenolate and the dialkyl chlorothiophosphate to give the amine hydrochloride and the dialkyl aryl thiophosphate. Considering that the formation of quaternary ammonium salts of dialkyl chlorothiophosphates and a tertiary amine proceeds very slowly at low temperature [2], the second explanation of the reaction mechanism seems most probable to us. The acceleration of the process in this case occurs as a result of the reaction being performed in a completely homogeneous medium due to the ready solubility of dialkyl chlorothiophosphates and amine salts of phenols in organic solvents.

Since the preparation of esters of thiophosphoric acid is of considerable interest, we also studied the reaction of phenols with phosphorus thiotrichloride in the presence of tertiary amines. We were able to isolate aryl dichlorothiophosphates, whose preparation by other methods presents certain difficulties. We studied this reaction on the example of phenol and p-nitrophenol.

EXPERIMENTAL

Reaction of phenols with dialkyl chlorothiophosphates. Into a flask with a reflux condenser, a mechanical stirrer and a dropping funnel was placed a mixture of 0.1 mole of phenol and 0.105 mole of triethylamine (or other amine) in 20-25 ml of solvent (bromo- or chlorobenzene, acetone or methyl, ethyl or isopropyl alcohols). The best yields of O,O-dialkyl-O₄-nitrophenylthiophosphates were obtained when isopropyl alcohol was used as solvent. The dialkyl chlorothiophosphate was gradually added to the reaction mixture with vigorous stirring

at 10-14°. The mixture was stirred for a further 3.5 hours at the same temperature and then 50-75 ml of water was added to it. The precipitated dialkyl aryl thiophosphate was separated (when the reaction was performed in hydrophobic solvents the solution was separated), washed with water, sodium carbonate solution and again with water, dried and vacuum distilled. The compounds obtained in this way and their properties are listed in the table.

Reaction of phenols with phosphorus thiotrichloride. Into a flask with a reflux condenser, a mechanical stirrer and a dropping funnel was placed a solution of 0.2 mole of phosphorus thiotrichloride in 50 ml of dry benzene and to it was gradually added a solution of 0.1 mole of phenol and 0.1 mole of triethylamine in 40 ml of dry benzene at such a rate that the temperature of the reaction mixture did not rise above 10-20°. After the reaction, the reaction mixture was separated from the precipitate, washed with water and the benzene and phosphorus thiotrichloride removed in vacuum. The residue was fractionated in high vacuum or purified by recrystallization. The compounds obtained and their properties are given in the table.

Formula	Yield (in %)	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	%P	
					found	calc.
$(CH_3)_2PSOC_6H_4NO_2-4$	77.5	158° (2); m.p. 36°	—	—	—	—
$CH_3O \rangle PSOC_6H_4NO_2-4$	80	120—121 (0.15)	1.3182	1.5470	—	—
$C_2H_5O \rangle PSOC_6H_4NO_2-4$	82	115 (0.04)	1.2655	1.5385	—	—
$(C_2H_5O)_2PSOC_6H_4NO_2-4$	60	117—122 (0.1)	1.1763	1.5110	12.25, 12.13	12.60
$(C_2H_5O)_2PSOC_6H_5$	47	150—154 (0.3)	1.3085	1.5285	9.98, 9.95	9.82
$(C_2H_5O)_2PSOC_6H_5Cl_2-2,4$	43	129 (13)	1.4050	1.5730	31.04	31.27*
$C_6H_5OPSCl_2$	53	130—135 (0.15); m. p. 54°	—	—	11.42, 11.23	11.40

* Analysis for chlorine.

SUMMARY

1. A study was made of the reaction of dialkyl chlorothiophosphates with phenols in the presence of triethylamine. It was shown that this reaction gave good yields of O,O-dialkyl-O-arylthiophosphates, which were apparently formed as a result of an exchange reaction.
2. The reaction of phenols with phosphorus thiotrichloride in the presence of triethylamine gave satisfactory yields of aryl dichlorothiophosphates.

LITERATURE CITED

- [1] N. N. Mel'nikov, *Prog. Chem.* 22, 253 (1953); G. Schrader, *Die Entwicklung neuer Insektizide auf Grundlage organischer Fluor- und Phosphor-Verbindungen*. 2. Auflag. Weinheim (1952); J. H. Fletcher, J. C. Hamilton, J. Heckenbleikner, E. L. Hoegbery, B. J. Sertl, and L. T. Cassaday, *J. Am. Chem. Soc.* 70, 3943 (1948); N. N. Mel'nikov, Ya. A. Mandel'baum and K. D. Shvetsova-Shilovskaya, *Chemical Methods of Plant Protection*, Moscow, Foreign Lit. Press, No. 3, 5 (1957).
- [2] D. F. Toy and T. M. Beck, *J. Am. Chem. Soc.* 72, 3191 (1950).
- [3] U. S. Patent, 2,471,464; *Ch. A.*, 43, 6659 (1949).
- [4] U. S. Patent, 2,692,891; *Ch. A.* 49, 12537 (1955).
- [5] P. S. Pishchemuka, *J. Russ. Chem. Soc.*, 44, 1406 (1912).

Received March 12, 1958

INVESTIGATIONS IN THE FIELD OF CONJUGATED SYSTEMS

XCVII. ADDITION OF ALCOHOLS TO VINYLALKYLACETYLENES IN THE PRESENCE OF KOH*

B. S. Kupin and A. A. Petrov

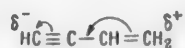
Lensoviet Technological Institute, Leningrad

The order of addition of various substances to vinylacetylene hydrocarbons depends particularly strongly on their structure and on the nature of the molecules added. Thus, for example, depending on the structure of the hydrocarbon, bromine may add predominantly in the 1,2-, 1,4- or 3,4-positions of the conjugated system of multiple bonds [1]. The same hydrocarbons may add bromine and iodine differently [1, 2]. All these peculiarities of the reactions of vinylacetylenes throw light on their mechanism and in general, on the mechanism of addition reactions at ethylene and acetylene bonds.

There is very great interest in the conversions of vinylalkylacetylenes, since here the effect of the alkyl on the conjugated system produces redistribution of the electron density in it. Continuing a systematic study of the addition reactions of vinylalkylacetylenes, we conducted experiments on the reaction of these hydrocarbons with alcohols in the presence of KOH.

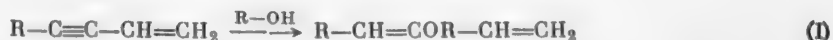
The reaction of vinylacetylene with alcohols has been studied thoroughly [3]. Depending on the conditions, it leads to 1,3-diene, allene or acetylene ethers or to saturated polyethers. However, in all cases, the alcohol is added in such a way that the first acetylene atom of the conjugated system acts as an electron donor. Hydrogen halides add to vinyl acetylene similarly [4].

All these data indicate a definite polarization of the vinylacetylene molecule (dipole moment 0.77 D) [5].



The addition of alcohols to vinylacetylene homologs with conjugated multiple bonds has only been studied on the example of isoalkenyl- and cycloalkenylacetylenes, i.e. hydrocarbons with a terminal acetylene grouping, and in most cases, the catalyst used was boron trifluoride [6, 7]. The order of addition of both alcohols and hydrogen halides [4] was similar to that reported for vinylacetylene.

In the light of these data it was to be expected that in the case of vinylalkylacetylenes, the addition of alcohols would proceed in the same way as with hydrogen halides [8, 9], i.e., with the formation of diene ethers of the type (I) or the products of their allyl or dieneacetylene rearrangement. Exactly this structure was ascribed by American chemists without proof to the product of the addition of 3 moles of methyl alcohol to vinyl ethylacetylene in the presence of BF_3 [10].



* Enyne compounds. XXV.

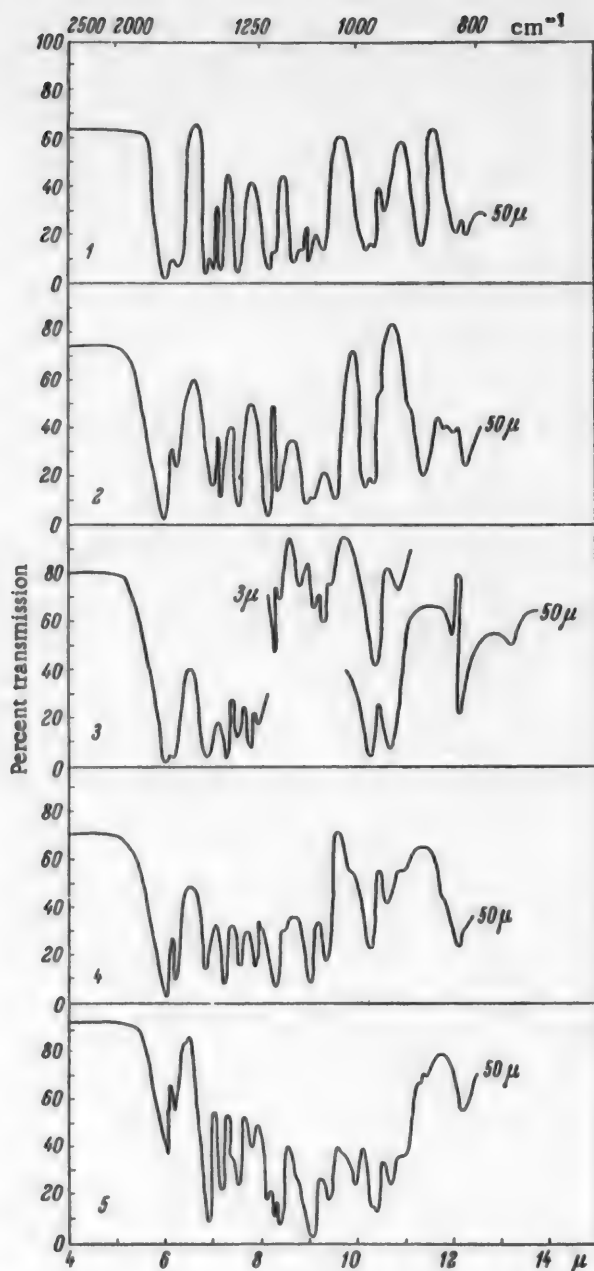
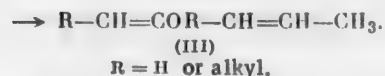
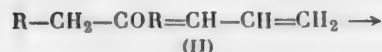
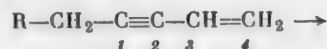


Fig. 1. Infrared transmission spectra of products of the addition of alcohols to vinylalkylacetylenes. 1) vinylmethylacetylene + CH_3OH , 2) vinylmethylacetylene + $\text{C}_2\text{H}_5\text{OH}$, 3) vinylethylacetylene + CH_3OH , 4) vinylethylacetylene + $\text{C}_2\text{H}_5\text{OH}$, 5) vinylethylacetylene + $\text{C}_2\text{H}_5\text{OH}$ in the presence of sodium alcoholate.

of a vinyl group (at a frequency of 1600 cm^{-1}). The spectrum of the methyl propenyl ketone we isolated agreed well with the spectrum of the trans form of this ketone presented in the literature (Fig. 2) [13].

We should note that ketones of the type (IV) and (V) differ sharply in constants and chemical properties, which excludes the possibility of any errors here.

However, our experiments led to other results: the addition of alcohols to vinylalkylacetylene proceeded predominantly by the scheme



A high-boiling substance was formed simultaneously, but we did not investigate this.

1. The unsaturated methyl and ethyl ethers obtained from vinylmethyl- and vinylethylacetylene contained only a conjugated system of double bonds and did not contain allene or acetylene groupings. This was demonstrated by a study of their infrared spectra. The ethers did not absorb in the region of 2200 cm^{-1} (frequency range of disubstituted acetylene bond) or in the region of 1950 cm^{-1} (frequency range of the allene grouping), while their spectra had two extremely intense bands in the region of 1600 cm^{-1} . The presence of two bands in this region is characteristic of diene ethers with conjugated multiple bonds [11] (Fig. 1). A change in the form of the alkaline catalyst (KOH , RONa) did not produce essential changes in the order of addition.

2. All the addition products of alcohols and vinylalkylacetylenes readily underwent hydrolysis in an acid medium with the formation of ketones of the type $\text{R}-\text{CO}-\text{CH}=\text{CH}-\text{CH}_3$ (IV). From ethers of formula (I) one would expect the formation of alkyl-vinyl ketones of the type $\text{R}-\text{CH}_2-\text{CO}-\text{CH}=\text{CH}_2$ (V) from ethers of formula (II), alkyl allyl ketones of the type $\text{R}-\text{CO}-\text{CH}_2-\text{CH}=\text{CH}_2$ (VI). However, it is known that the latter are readily converted into alkyl propenyl ketones in an acid medium [12].

The infrared spectra of the ketones we obtained did not indicate the presence

Hydrogenation of the ketone obtained from vinylmethylacetylene over Pd/CaCO_3 formed methyl propyl ketone. The latter was identified by its constants and the melting point of its 2,4-dinitrophenylhydrazone.

3. Hydrogenation of the ether $\text{C}_5\text{H}_7\text{OCH}_3$ formed the methyl ether of pentanol-2 together with methyl propyl ketone. Evidently the palladium catalyst produced partial hydrolysis of the enol ether and the methyl propenyl ketone thus formed was hydrogenated to the saturated ketone.

Thus, it was established that alcohols add to vinylalkylacetylenes at the acetylene bond and in the reverse order to that for hydrogen halides.

Comparison of the infrared spectra of the ethers obtained from vinylmethyl and vinyl ethylacetylene led to the conclusion that they were not homologs of monotypic structure. The ethers from vinyl ethylacetylene definitely lacked a vinyl group (the frequencies at 986, 1420 and 6100 cm^{-1} were absent). The conjugated system of bonds corresponded to the frequencies 1655 and 1615 cm^{-1} , while the same system in the ethers obtained from vinylmethylacetylene was characterized by the frequencies 1650 and 1580 cm^{-1} . These facts led to the conclusion that the addition of alcohols to vinylalkylacetylenes is accompanied by isomerization of (II) \rightarrow (III) and in the case of vinyl ethylacetylene this isomerization proceeds to completion.

The infrared spectra of ethers from vinyl ethylacetylene corresponded completely with formula (III) (where $\text{R} = \text{CH}_3$). They showed strong absorption in the region of 960 cm^{-1} (the grouping $-\text{CH}=\text{CH}-$) and in the region of 830 cm^{-1} (apparently the grouping $-\text{CH}=\text{C}<$).

Ethers of structure (II) and (III) give identical products on hydrolysis or exhaustive hydrogenation. Ozonization was a suitable chemical method for proving the structure of the ethers examined and this gave only acetic acid. Thus formula (II) is excluded and formula (III) (with $\text{R} = \text{CH}_3$) is confirmed.

The ethers obtained from vinylmethylacetylene were most likely mixtures of substances with formulas (II) and (III) ($\text{R} = \text{H}$). The presence of (II) in this mixture of ethers was indicated by intense frequencies of 1420, 988 and 828 cm^{-1} and also the frequency 6100 cm^{-1} in the infrared spectrum, while the spectrum also had frequencies indicating the presence of ether (III) (966 and 880 cm^{-1}). Partial isomer-

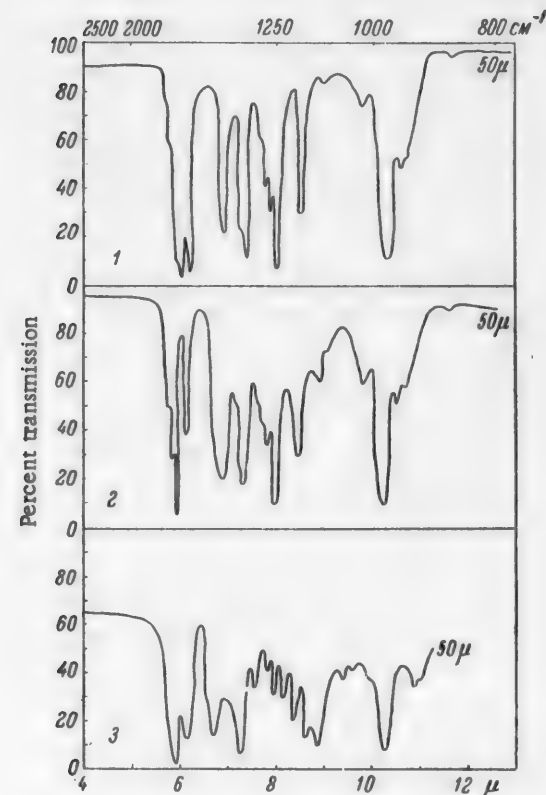


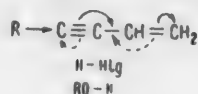
Fig. 2. Infrared transmission spectra of ketones. 1) methyl propenyl ketone (literature data); 2) methyl propenyl ketone (our data); 3) ethyl propenyl ketone.

ization of (II) into (III) and cis-trans isomerism were apparently the reasons for the quite indefinite boiling points of the substances obtained and also some variation in their constants from experiment to experiment without obvious reason.

This investigation revealed a very important phenomenon, which required theoretical explanation: the order of addition of alcohols and hydrogen halides to vinylalkylacetylenes did not conform. In the case of hydrogen halides the triple bond was the donor and in the case of alcohols, the acceptor of electrons. Consequently, depending on the addend, the distribution of electron density in the vinylalkylacetylene molecule changed radically.

In our opinion, these fundamental differences in orientation are connected with differences in the mechanism of the addition of hydrogen halides and alcohols and the slight polarity of vinylalkylacetylenes.

The addition of alcohols proceeds as a result of nucleophilic attack, which can only lead to addition at the acetylene bond under the given conditions. The first atom of the acetylene grouping will be the most positively polarized. It is also the position of the initial attack and attachment of the anion.



In the case of the addition of hydrogen halides, electrophilic attack is possible both at the ethylene and the acetylene bonds; however, the acetylene bond is preferred [14]. An electrophilic attack at the acetylene bond produces a displacement of electron density towards this bond and as a result of this, the first acetylene atom of the conjugated system becomes the most electronegative.

EXPERIMENTAL

Addition of CH_3OH to vinylmethylacetylene. Five glass tubes were each charged with 4.2 g of hydrocarbon, 6 g of CH_3OH and 3.5 g of powdered KOH (molar ratio of 1:3:1). The tubes were sealed and heated at 150–155° for 7 hours. The yellow oil with a greenish tinge obtained was steam distilled; about 2 g of tar was left in the flask. The upper layer of the distillate was washed with saturated CaCl_2 solution and dried with fused potassium carbonate.

Distillation of the 22 g of material in a vacuum of 100 mm yielded 14 g of a fraction boiling at 54–56° (diene ether), about 2 g of a mixture of ether with unreacted hydrocarbon (fraction up to 54°) and 4 g of residue.

At normal pressure, the diene ether boiled at 110–112°. Its specific gravity (d_4^{20}) varied from experiment to experiment in the limits 0.8381–0.8442 and the refractive index (n_D^{20}) in the limits 1.4582–1.4660. The analytical data and general character of the infrared spectra did not change. They are presented for a sample with the following constants: d_4^{20} 0.8416, n_D^{20} 1.4650, M_{rD} 32.24; calc. 30.61.

Found % C 73.40, 73.68; H 10.41, 10.38. $\text{C}_6\text{H}_{10}\text{O}$. Calculated % C 73.46; H 10.20.

Infrared spectra: • 790 strong, 814 strong, 828 strong, 879 strong, 945 average, 966 strong, 986 strong, 1074 strong, 1110 strong, 1118 strong, 1149 strong, 1198 strong, 1216 strong, 1320 strong, 1387 strong, 1422 strong, 1453 strong, 1580 strong, 1651 very strong, 2836 strong, 2852 strong, 2998 very strong, 3090 average, 3124 weak, cm^{-1} .

2.98 g of the diene ether (fraction 55–56° at 100 mm) was hydrogenated in methanol solution in the presence of Pd/ CaCO_3 (4 g). The catalyst was first reduced (58 ml of H_2). Over a period of 8 hours, 1347 ml of H_2 (757.4 mm, 16°) was absorbed and this corresponds to 91.1% of theoretical.

The hydrogenation product contained methyl propyl ketone. Treatment of it with 2,4-dinitrophenylhydrazine yielded a 2,4-dinitrophenylhydrazone with m. p. 139° (literature data for the 2,4-dinitrophenylhydrazone of methyl propyl ketone [18]; m. p. 141°).

To remove the ketone, the hydrogenation products were distilled over phenylhydrazine; this gave the methyl ether of pentanol-2.

B. p. 87.5–88.5°, d_4^{20} 0.7597, n_D^{20} 1.3840. Literature data [15]: b. p. 88–88.5°, d_4^{20} 0.7569, n_D^{20} 1.3840.

10 g of the diene ether (fraction 55–56° at 100 mm) was shaken for 1 hour with 70 ml of 10% sulfuric acid. The mixture was then saturated with ammonium sulfate and the ketone separated washed with a saturated solution of CaCl_2 and dried over sodium sulfate. We obtained 6 g (70%) of methyl propenyl ketone with the following constants:

*The infrared spectra were mainly plotted on an IKS-12 spectrograph up to 5.5 μ with a LiF prism and then with an NaCl prism. The authors would like to thank T. V. Yakovleva for help in studying the spectra.

b. p. 118-121°, d_4^{20} 0.8597, n_D^{20} 1.4350.

Infrared spectrum: 864 weak, 937 average, 949 average, 976 very strong, 1021 average, 1104 weak, 1120 average, 1183 strong, 1257 very strong, 1279 average, 1293 average, 1314 average, 1372 very strong, 1444 very strong, 1638 strong, 1687 very strong, 1700 average, 1720 average, cm^{-1} .

The 2,4-dinitrophenylhydrazone formed orange crystals with m. p. 153° (after two recrystallizations from alcohol).

Found % N 21.36, 21.27. $\text{C}_{11}\text{H}_{13}\text{O}_4\text{N}_4$. Calculated % N 21.21.

All these data are similar to those presented in the literature for transmethyl propenyl ketone [13, 15].

The ketone (2.5 g) was dissolved in methyl alcohol (20 ml) and hydrogenated to saturation over Pd/CaCO₃. 724 ml of H₂ (742 mm, 16°) was absorbed, which represents 99.7% of the calculated amount. Then the mixture was diluted with ether and washed twice with saturated CaCl₂ solution. After removal of the ether we obtained about 1.2 g of methyl propyl ketone with b. p. 100-102° and n_D^{20} 1.3998, which agrees with literature data [16]. The ketone was steam distilled from the aqueous solutions and bound as the 2,4-dinitrophenylhydrazone (0.9 g). Thus, the total yield of ketone was about 1.7 g. The 2,4-dinitrophenylhydrazone formed orange prisms with m. p. 141° (from alcohol). It did not depress the melting point of the 2,4-dinitrophenylhydrazone of authentic methyl propyl ketone, but did so with the analogous derivative of diethyl ketone.

Addition of C₂H₅OH to vinylmethylacetylene. Under the conditions described above 16.8 g of vinylmethylacetylene yielded 5 g of ethyl pentadienyl ether and 4.5 g of high-boiling products. For ethyl pentadienyl ether we found:

B. p. 69-71° (100 mm), d_4^{20} 0.8338, n_D^{20} 1.4542, M_R^D 36.44; calc. 36.23.

Found % C 75.13, 74.91; H 10.76, 10.90. $\text{C}_7\text{H}_{12}\text{O}$. Calculated % C 75.00; H 10.71.

Infrared spectrum: 815 strong, 829 weak, 844 weak, 878 average, 896 average, 949 weak, 965 strong, 983 strong, 1038 strong, 1102 strong, 1108 strong, 1185 strong, 1221 strong, 1318 strong, 1388 strong, 1415 strong, 1580 strong, 1650 very strong, cm^{-1} .

Hydrolysis of the ether yielded a ketone forming a 2,4-dinitrophenylhydrazone with m. p. 155-156°.

Addition of CH₃OH to vinyl ethylacetylene. Under the same conditions, 40 g of vinyl ethylacetylene yielded 38.4 g of an oil which steam distilled. Distillation on a Widmer fractionating column yielded 18 g of unreacted hydrocarbon, 12 g of methyl hexadienyl ether and 6 g of high-boiling products.

For the methyl hexadienyl ether (3-methoxyhexadiene-2,4) we found:

b. p. 45-46° (20 mm), 78-80° (100 mm), d_4^{20} 0.8503, n_D^{20} 1.4752, M_R^D 37.15; calc. 35.23.

Found % C 75.16, 75.09; H 10.75, 11.04. $\text{C}_7\text{H}_{12}\text{O}$. Calculated % C 75.00; H 10.71.

Infrared spectrum: 760 average, 831 average, 935 strong, 966 very strong, 1056 weak, 1074 average, 1098 average, 1134 average, 1188 average, 1207 strong, 1260 average, 1284 strong, 1330 average, 1369 strong, 1450 strong, 1615 very strong, 1655 very strong, cm^{-1} .

5.9 g of ether was shaken for 1 hour with 50 ml of 10% sulfuric acid. The ketone obtained was salted out with ammonium sulfate, dried with sodium sulfate and distilled.

B. p. 75.5-76.5° (100 mm), 135-137° (760 mm), d_4^{20} 0.8487, n_D^{20} 1.4350.

Infrared spectrum: 912 weak, 920 weak, 972 very strong, 1042 weak, 1064 weak, 1118 strong, 1160 strong, 1198 strong, 1227 average, 1254 average, 1281 weak, 1322 average, 1365 strong, 1450 strong, 1638 very strong, 1680 very strong, 1708 weak, 1720 very weak, cm^{-1} .

Treatment with 2,4-dinitrophenylhydrazine yielded a substance with m. p. 163-164° (from alcohol).

All these data are similar to those presented in the literature for ethyl propenyl ketone [12, 13].

The ozonide, obtained from 3.17 g of the original methyl hexadienyl ether, was decomposed with hydrogen peroxide and the ozonization products extracted with ether. Removal of the ether yielded only acetic acid,

distilling at 45-48° (60 mm). It gave a positive indigo test by Flegl's method [17].

Heating vinyl ethylacetylene with methyl alcohol in the presence of sodium alcoholate at the same temperature gave a considerably lower yield (2.5 g) of the same diene ether: b. p. 78-80° (100 mm), n_D^{20} 1.4449. Its infrared spectrum is shown in Fig. 1. The substance was not examined more closely.

Addition of C_2H_5OH to vinyl ethylacetylene. Under the same conditions, from 26.1 g of vinyl ethylacetylene we obtained 24 g of an oil, from which 13.1 g of the original hydrocarbon was recovered by distillation. The yield of the ethyl ether of hexadienol (apparently 4-ethoxyhexadiene-2,4) was 6.2 g. The residue was 3.9 g.

B. p. 93.5-95.5° (100 mm), d_4^{20} 0.8346, n_D^{20} 1.4650, MR_D 41.780; calc. 39.85.

Found %: C 76.34, 76.23; H 10.98, 11.08. $C_8H_{14}O$. Calculated %: C 76.19; H 11.11.

Infrared spectrum: 828 strong, 912 weak, 934 average, 965 very strong, 1069 strong, 1115 strong, 1206 strong, 1255 very weak, 1286 average, 1330 weak, 1380 strong, 1452 strong, 1615 strong, 1655 very strong, cm^{-1} .

SUMMARY

1. It was established that alcohols add to vinylalkylacetylenes (penten-1-yne-3 and hexen-1-yne-3) in the presence of KOH at the acetylene bond in the reverse order in comparison with hydrogen halides.
2. It was shown that the initial addition products underwent isomerization with transposal of the conjugated system of bonds.
3. An explanation was given for the differences in the order of addition of alcohols and hydrogen halides, based on hypotheses on the nucleophilic and electrophilic character of addition reactions.

LITERATURE CITED

- [1] A. A. Petrov and Yu. I. Porfir'eva, J. Gen. Chem. 23, 1867 (1953)*; 27, 1805 (1957)*.
- [2] A. A. Petrov, Yu. I. Porfir'eva, T. V. Yakovleva and K. S. Mingaleva, J. Gen. Chem., 28, 2320 (1958)*.
- [3] A. A. Petrov, Prog. Chem. 21, 452 (1952).
- [4] A. A. Petrov, Prog. Chem. 13, 203 (1944).
- [5] H. Zumbroso and R. Passerini, Bull. Soc. Chim. 1956, 1608.
- [6] A. L. Zakharova, Sci. Rep. Leningrad State University, No. 11, 162 (1936).
- [7] L. A. Favorskaya, et al., J. Gen. Chem. 23, 47 (1953)*; 24, 242 (1954)*; 25, 1477 (1955)*; 27, 2406 (1957).
- [8] R. A. Jacobson and W. H. Carothers, J. Am. Chem. Soc. 55, 1624 (1933).
- [9] E. A. Leporskaya and A. A. Petrov, J. Gen. Chem. 23, 1471 (1953)*.
- [10] D. B. Killian, G. F. Hennion and J. A. Nieuwland, J. Am. Chem. Soc. 58, 892 (1936).
- [11] A. A. Petrov and G. I. Semenov, J. Gen. Chem., 28, 71 (1958)*.
- [12] L. N. Nazarov and L. I. Zaretskaya, J. Gen. Chem. 27, 624 (1957)*.
- [13] R. Heilmann, G. de Gaudemaris, and P. Anaud, C.r., 240, 1995 (1955); Bull. Soc. Chim., 1957, 119.
- [14] A. A. Petrov, J. Gen. Chem., 26, 3318 (1956)*.
- [15] T. A. Zyryanova and A. A. Petrov, J. Gen. Chem. 26, 1918 (1956).
- [16] M. K. Kochetkov, Bull. Acad. Sci. USSR, Div. Chem. Sci. 1954, 47;* Dict. of Organic Compounds (1949) [In Russian].

*Original Russian pagination. See C.B. Translation.

[17] K. H. Bauer, *Die organische Analyse*, Leipzig, 286 (1954).

[18] *Dict. of Organic Compounds*, II, 800 (1949) [In Russian].

Received February 28, 1958

DIENE CONDENSATIONS OF GEM-SUBSTITUTED BUTADIENES

II. 1,1,2-TRIMETHYLBUTADIENE.

I. N. Nazarov* and M. V. Mavrov

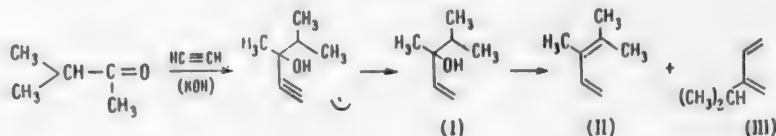
Institute of Organic Chemistry, Academy of Sciences, USSR

In a previous investigation [1] we showed that 1,1-dimethylbutadiene and diisobutenyl only underwent diene synthesis with preliminary isomerization into 1,3-disubstituted dienes, while in the case of 1,1,4-trimethylbutadiene, together with adducts corresponding to the isomerized form of the diene, the normal condensation product was also formed.

Continuing the systematic investigation of gem-substituted dienes in diene synthesis, we studied the behavior of yet another diene of this type: 1,1,2-trimethylbutadiene (II).

The synthesis of this diene and its diene condensations were first described by Naves [2, 3], who ascribed a "meta"-isomer structure to its adduct with crotonaldehyde [3]. This conclusion is in contradiction to existing rules of structural direction of diene synthesis and naturally required checking.

Diene (II) was obtained by the following method. By condensation of methyl isopropyl ketone with acetylene under pressure, we obtained methylisopropylethynylcarbinol, which, after partial hydrogenation of the triple bond and dehydration, was converted into diene (II).



On the basis of the Wagner-Zaitsev rule, together with the predominant formation of diene (II), one would also expect the formation of 2-isopropylbutadiene (III) in the dehydration of methylisopropylvinylcarbinol (I). Naves and Ardizio [2] studied the dehydration of alcohol (I) over potassium bisulfate and obtained a hydrocarbon with b. p. 104-108°, which was diene (II) in their opinion.

We studied the dehydration of carbinol (I) over potassium bisulfate, magnesium sulfate and also over 20% zirconium dioxide on pumice. It was found that the dehydration product was a mixture of both possible dienes (II) and (III), which contained only 30-40% of the geminal diene (II), according to data from fractional distillation on a column of 39 theoretical plates.

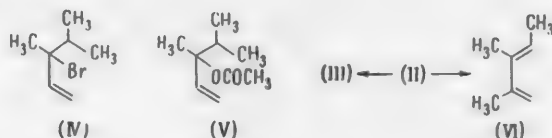
Changing the dehydration conditions of carbinol (I) (temperature and rate of throughput) over zirconium dioxide did not have any appreciable effect on the ratio of isomers (II) and (III) in the mixture. The structure of dienes (II) and (III) was proved by oxidation with potassium permanganate and also by their behavior in diene synthesis. Attempts to use other methods for the preparation of diene (II) did not lead to the desired results.

* Deceased.

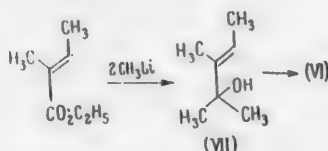
** In Naves' experiment, the starting alcohol (I) contained up to 25% of saturated alcohol.

Thus, the dehydrobromination of bromide (IV) of the corresponding unsaturated alcohol (I) with sodium hydroxide in ethylene glycol or potassium hydroxide gave a hydrocarbon mixture containing only about 20% of diene (II). As would be expected, pyrolysis of the acetate of methylisopropylvinylcarbinol (V) led to only the formation of 2-isopropylbutadiene (III).

Like the diene studied previously [1], under the conditions of diene synthesis, diene (II) partially isomerized into dienes (III) and (VI).

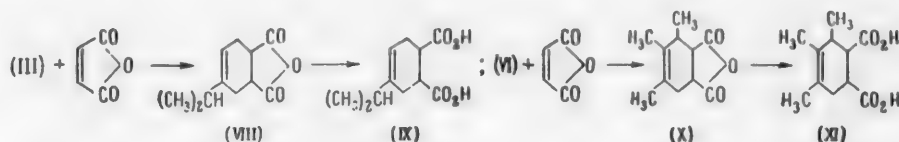


Therefore, for comparison a study was made of the diene condensation of these three isomeric dienes. 1,2,3-Trimethylbutadiene (VI) was obtained by the following scheme.



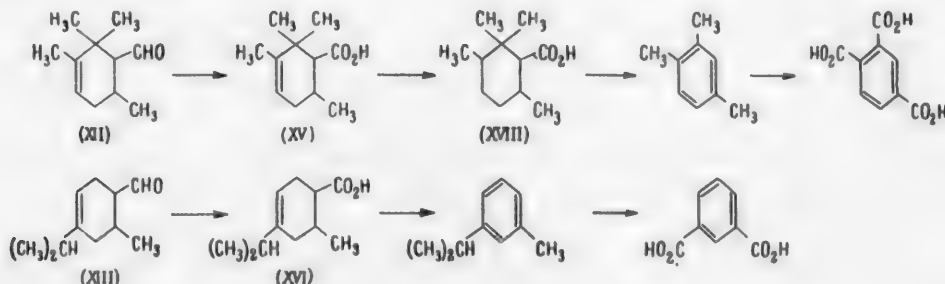
Condensation of ethyl α -methylcrotonate with methyl lithium yielded dimethyl-(α -methyl)-propenylcarbinol (VII), which was readily converted into diene (VI) by dehydration over zirconium dioxide.

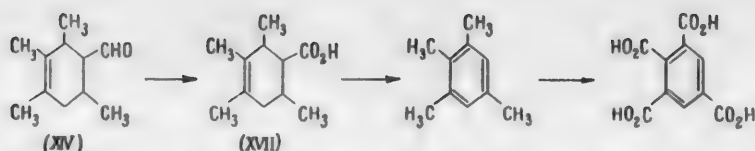
Dienes (II) and (VI) reacted with maleic anhydride to give almost quantitative yields of adducts (VIII) and (X), respectively, and hydrolysis of the latter yielded the dicarboxylic acids (IX) and (XI) corresponding to them.



1,1,2-Trimethylbutadiene (II) underwent diene synthesis with various dienophiles comparatively readily. However, even at 100° with maleic anhydride it formed adduct (X), corresponding to 1,2,3-trimethylbutadiene (VI), while Alder [4] presented data on the isomerization of diene (II) into diene (III) in the condensation with maleic anhydride.

Interesting results were obtained in a study of the diene condensation of 1,1,2-trimethylbutadiene with unsymmetrical dienophiles. Heating 1,1,2-trimethylbutadiene with crotonaldehyde at 140° for 10 hours or at 200° for 2 hours gave about a 70% yield of a mixture of adducts (XII), (XIII) and (XIV), corresponding to all three possible isomeric dienes.

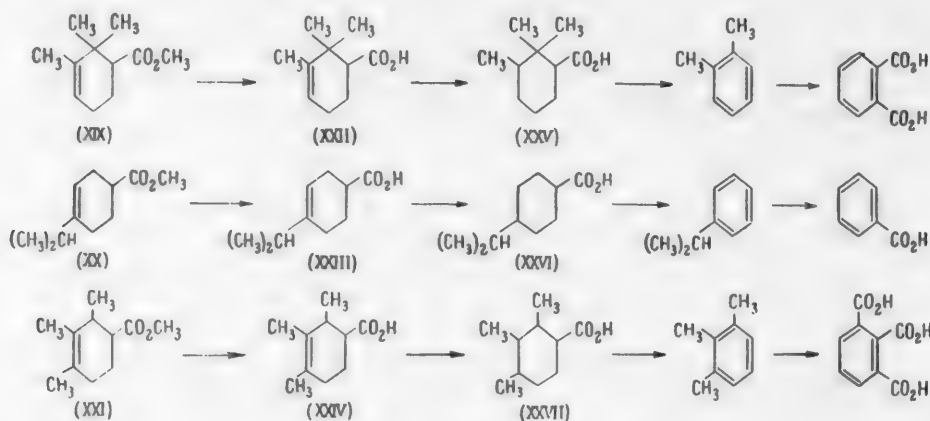




Oxidation of the mixture of aldehydes obtained with moist silver oxide gave a mixture of acids (XV-XVII), from which it was possible to isolate crystalline 2,2,3,6-tetramethyl- Δ^3 -tetrahydrobenzoic acid (XV) in a yield of 20-25%. Its structure was established by hydrogenation into acid (XVIII), which was converted into trimellitic acid by dehydrogenation over chromium oxide on aluminum oxide at 480° and subsequent oxidation.

The liquid mixture of unsaturated acids (75-80%) left after isolation of crystalline acid (XV) was dehydrogenated under the same conditions and gave a 50% yield of a mixture of aromatic hydrocarbons. Oxidation of the latter with dilute nitric acid under pressure yielded a mixture of acids, from which it was possible to isolate only isophthalic acid directly. Prehnitic acid was isolated from the residual mixture of acids as the crystalline methyl ester. The residue was mainly the liquid ester of trimellitic acid. On the basis of an approximate estimation of the yields of the corresponding benzoic acid, the ratio of the isomeric aldehydes (XII), (XIII) and (XIV) obtained in the mixture was approximately 2 : 1 : 1.

1,1,2-Trimethylbutadiene also underwent diene synthesis with acrylonitrile and methyl acrylate at 200°. The condensation product of 1,1,2-trimethylbutadiene with methyl acrylate (66%) was a mixture of at least three isomers (XIX), (XX) and (XXI), whose presence was demonstrated by the following series of conversions.

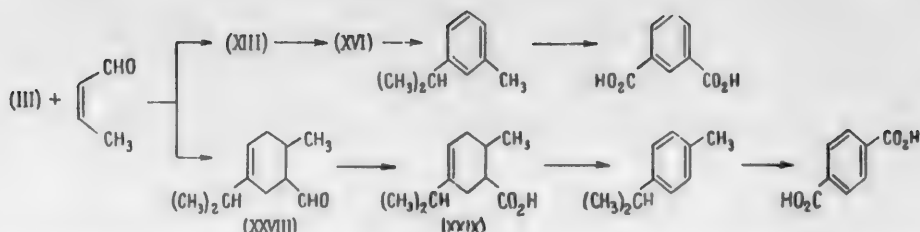


Hydrolysis of the mixture of esters (XIX-XXI) with sodium hydroxide solution and subsequent hydrogenation over a Pt-catalyst yielded a liquid mixture of acids (XXV-XXVII). The structures of the latter were established by their dehydrogenation over $\text{Cr}_2\text{O}_3/\text{Al}_2\text{O}_3$ with simultaneous decarboxylation and oxidation of the aromatic hydrocarbons obtained into the corresponding acids. This gave benzoic, o-phthalic and hemimellitic acids in a ratio of approximately 1 : 2 : 5.

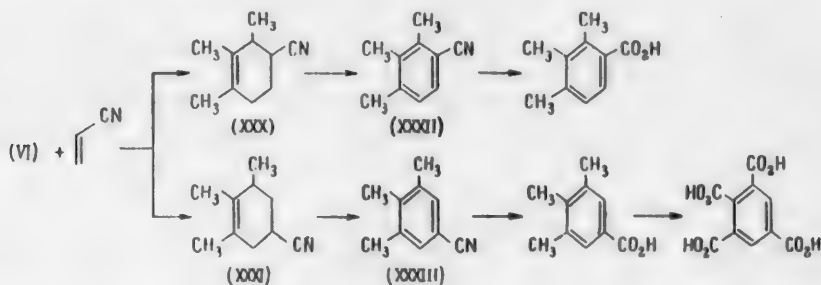
Due to the isomerization of 1,1,2-trimethylbutadiene under the conditions of diene synthesis, it was not possible to study the structural direction of its condensation with unsymmetrical dienophiles; however, we studied this problem in detail on the example of the condensation of dienes (III) and (VI) with unsymmetrical dienophiles.

It was found that in these cases condensation proceeded normally with the formation of both possible structural isomers. Thus, 2-isopropylbutadiene (III) reacted with crotonaldehyde at 200° to give an 80% yield of a mixture of aldehydes (XIII) and (XXVIII) in the ratio 3 : 1.

The oxidation of this mixture with moist silver oxide yielded a mixture of liquid acids (XVI) and (XXIX), which were dehydrogenated over 20% palladium on charcoal and the p- and m-cymenes formed were then oxidized with chromium trioxide to give isophthalic and terephthalic acids in a ratio of 3 : 1.



The structural direction of the condensations of 1,2,3-trimethylbutadiene was studied on the example of its condensation with acrylonitrile. When a mixture of the components was heated at 200° a mixture of the adducts (XXX) and (XXXI) was formed in 60% yield.



Dehydrogenation of the mixture of nitriles (XXX) and (XXXI) over 20% palladium on charcoal produced a mixture of crystalline and liquid nitriles (XXXII) and (XXXIII). Hydrolysis of the crystalline nitrile yielded 2,3,4-trimethylbenzoic acid. After hydrolysis of the liquid mixture of nitriles, it was possible to isolate 3,4,5-trimethylbenzoic acid and oxidation of this gave prehnitic acid. The content of the "meta"-isomer in the original mixture of adducts was about 5-7%.

EXPERIMENTAL

Methylisopropylvinylcarbinol (I). 616 g of methylisopropylethynylcarbinol (b. p. 134-134.5° at 752 mm and n_D^{20} 1.4370), obtained by condensation of methyl isopropyl ketone with acetylene under pressure [5], was selectively hydrogenated in the presence of 1 g of 2% palladium on calcium carbonate (pressure 3 atm, 30-35°). Distillation on a column (20 theoretical plates) gave 480 g (75%) of methylisopropylvinylcarbinol.

B. p. 130.7-131° (748 mm), n_D^{20} 1.4361, d_4^{20} 0.8393, MR_D 35.48; calc. 35.58.

Found %C 73.65, 73.74; H 12.28, 12.08. $C_7H_{14}O$. Calculated %C 73.63; H 12.36.

Dehydration of methylisopropylvinylcarbinol (I). 1) Over zirconium dioxide on pumice. Passing 228 g of carbinol at 290-300° over zirconium dioxide with a rate of 0.9-1 ml/min formed 158.4 g of a mixture of hydrocarbons (II) and (III) (b. p. 84-106°, n_D^{25} 1.4401) and 21.0 g of the original carbinol (b. p. 128-132°, n_D^{25} 1.4308). The yield of hydrocarbons was 82% on the amount passed and 92% on the carbinol which reacted.

Fractionation of the mixture of hydrocarbons obtained over sodium on a column of 39 theoretical plates gave two fractions.

The first fraction was 81 g of 2-isopropylbutadiene (III).

B. p. 86-87°, n_D^{20} 1.4324, d_4^{20} 0.7241, MR_D 34.51; calc. 33.59. λ_{max} 224 m μ , ϵ 18600 (heptane).

Literature data [6]: b. p. 85-86°, n_D^{20} 1.4340, d_4^{20} 0.723.

The oxidation of 3 g of this diene with an aqueous solution of potassium permanganate at 0° gave 1.3 g of isobutyric acid, whose p-bromophenacyl ester melted at 75-76° and did not depress the melting point of an authentic sample.

The second fraction (b. p. 107-109°), weighing 44 g, contained mainly 1,1,2-trimethylbutadiene (II), which had the following constants after a second distillation on a column:

b. p. 108-8.5° (747 mm), n_D^{20} 1.4691, d_4^{20} 0.7544, MR_D 35.51; calc. 33.59, λ_{\max} 234 m μ , ϵ 22300 (heptane). Literature data [2]: b. p. 104-108°, n_D^{20} 1.4560.

Oxidation of 2.5 g of diene (II) with potassium permanganate at 0° gave 0.7 g of acetone and 1.2 g of a mixture of acetic and formic acids.

2) Over potassium bisulfate. When 57 g of carbinol (I) was heated to 140° with 7 g of potassium bisulfate, we obtained 32.8 g (70%) of a mixture of hydrocarbons (II) and (III) (b. p. 90-110°, n_D^{21} 1.4458), containing 11.2 g of diene (III) and 10.7 g of diene (II).

3) Over magnesium sulfate. Passing 57 g of carbinol (I) over freshly fired magnesium sulfate at 300-310° at a rate of 0.3-0.4 ml/min yielded 28.1 g (60%) of a mixture of hydrocarbons (b. p. 85-108°, n_D^{24} 1.4439). By fractional distillation on a column, we isolated 9.2 g of diene (III) and 8.7 g of diene (II).

3,4-Dimethyl-3-bromopentene (IV). With cooling and vigorous stirring, a solution of 57 g of carbinol (I) in 30 ml of benzene was added to a solution of 45 g of freshly distilled phosphorus tribromide in 50 ml of absolute benzene at such a rate that the temperature of the reaction mixture did not exceed +5°. Stirring was continued at room temperature for 5 hours. Vacuum distillation of the reaction product yielded 72 g (81%) of bromide (IV) with b. p. 81-82° (58 mm), n_D^{20} 1.4841.

Found %: Br 44.82, 44.73. $C_7H_{13}Br$. Calculated %: Br 45.12.

Dehydrobromination of bromide (IV). a) Heating 30 g of bromide (IV) to 180° with 20 g of solid 85% potassium hydroxide gave 11 g of a mixture of dienes (II) and (III) with b. p. 85-104°, n_D^{19} 1.4412.

b) With vigorous stirring, 30 g of bromide (IV) was added to a suspension of 30 g of sodium hydroxide in 75 ml of ethylene glycol, heated to 220-225°. We obtained 12.4 g (80%) of a mixture of dienes (II) and (III) with b. p. 85-105°, n_D^{21} 1.4406. Fractionation of the combined fractions of dienes on a column gave 12.2 g of diene (III) and 5.3 g of diene (II).

Acetate of methylisopropylvinylcarbinol (V). 57 g of carbinol (I) was added dropwise to boiling acetic anhydride (153 g). The mixture was boiled for a further 5 hours, cooled and poured into a saturated solution of sodium carbonate, cooled to 0°. We obtained 65 g (84%) of the acetate (V) with b. p. 72-75° (40 mm), n_D^{20} 1.4292.

Found %: C 69.47, 69.24; H 10.63, 10.45. $C_9H_{16}O_2$. Calculated %: C 69.19; H 10.32.

Pyrolysis of acetate (V). 62 g of the acetate was passed through a quartz tube filled with quartz pieces (d 20 mm, l 50 cm) at 470° in a stream of nitrogen at a rate of 1.3-1.4 ml/min. Two distillations of the pyrolysis product obtained yielded 21.2 g (55%) of 2-isopropylbutadiene with b. p. 85-87°, n_D^{17} 1.4319 and 21.0 g of the starting acetate with b. p. 158-164°, n_D^{17} 1.4298.

Dimethyl- α -methylpropenylcarbinol (VII). Over a period of 3 hours, a solution of 62 g of ethyl α -methylcrotonate (b. p. 50-56° at 18 mm, n_D^{21} 1.4326) in 150 ml of ether was added with cooling to -8° to an ether solution of methylolithium, prepared from 15.2 g of lithium and 145 g of methyl iodide in 700 ml of absolute ether. The reaction mixture was boiled under reflux for 1.5 hours. The lithium alcoholate was decomposed with ice water and the ether layer separated, dried with potassium carbonate and distilled. We obtained 40.3 g (72%) of carbinol (VII) with b. p. 129-131°, n_D^{20} 1.4467.

Found %: C 73.38, 73.45; H 11.98, 12.10. $C_7H_{14}O$. Calculated %: C 73.63; H 12.36.

1,2,3-Trimethylbutadiene (VI). The dehydration of 38 g of carbinol (VII) over 20% zirconium dioxide on pumice at 310° yielded 24 g (80%) of hydrocarbon (VI) with b. p. 104-106°, n_D^{25} 1.4582. After distillation on a column, the 1,2,3-trimethylbutadiene (VI) had the following constants:

b. p. 106.8-107° (750 mm), n_D^{20} 1.4624, λ_{\max} 232.5 m μ , ϵ 23400 (heptane).

Found %: C 87.42, 87.51; H 12.46, 12.53. C_7H_{12} . Calculated %: C 87.42; H 12.58.

Condensation of isomeric dienes (II), (III) and (VI) with maleic anhydride. a) A mixture of 6 g of 2-isopropylbutadiene (III), 6 g of maleic anhydride, 30 ml of benzene and 0.01 g of pyrogallol was heated in a glass ampule for 5 hours at 100°. Removal of the solvent and crystallization of the residue from petroleum ether yielded 9.8 g (81%) of anhydride (VIII) with m. p. 86.5-87°.

Found %: C 68.05, 68.13; H 7.42, 7.26. $C_{11}H_{14}O_3$. Calculated %: C 68.02; H 7.26.

For hydrolysis a suspension of 5.0 g of anhydride (VIII) in 60 ml of 2% sodium hydroxide was boiled until solution was complete (50 minutes). The solution was extracted with ether and the aqueous layer acidified with 10% hydrochloric acid. We isolated 4.8 g of acid (IX) with m. p. 168° (from dilute hydrochloric acid).

Found %: C 61.88, 61.96; H 7.67, 7.70. $C_{11}H_{16}O_4$. Calculated %: C 62.24; H 7.59.

b) A mixture of 3.0 g of 1,2,3-trimethylbutadiene (VI) and 3.0 g of maleic anhydride was heated for 6 hours under the above conditions. We isolated 4.9 g of the anhydride (X) with m. p. 87-87.5° (from heptane).

Found %: C 67.87, 67.76; H 7.26, 7.19. $C_{11}H_{14}O_3$. Calculated %: C 68.02; H 7.26.

A mixture with anhydride (VIII) melted at 60-72°. Hydrolysis of 3.0 g of anhydride (X) by the procedure described above yielded 2.7 g of acid (XI) with m. p. 167° (from 35% methanol). A mixture with acid (IX) melted at 153-158°.

Found %: C 62.07, 61.94; H 7.56, 7.51. $C_{11}H_{16}O_4$. Calculated %: C 62.24; H 7.59.

c) A mixture of 3 g of 1,1,2-trimethylbutadiene (II) and 3 g of maleic anhydride was heated for 16 hours. We obtained 2.4 g of anhydride (X) with m. p. 87° (from heptane), which did not depress the melting point of the sample described above.

Hydrolysis with 2% sodium hydroxide solution gave acid (XI), identical with that described above. Under other conditions also (60°, 60 hours, yield 35%; 120°, 5 hours, yield 40%) the same anhydride (X) was always obtained. In one of the early experiments only and for unknown reasons a different result was obtained.

d) A mixture of 2 g of diene (II), 10 ml of benzene and 2 g of maleic anhydride was heated under analogous conditions for 15 hours. After two recrystallizations from a mixture of benzene and petroleum ether, a condensation product (0.8 g) melting at 86-86.5° was obtained. A mixture with anhydride (VIII) melted at 52-59°.

Found %: C 68.02, 68.01; H 7.51, 7.42. $C_{11}H_{14}O_3$. Calculated %: C 68.02; H 7.26.

Hydrolysis of 0.8 g of this adduct yielded 0.5 g of acid with m. p. 176° (from 30% alcohol). A mixture with acid (IX) melted at 145-149° and with acid (XI), at 155-158°.

Found %: C 62.28, 62.21; H 7.51, 7.46. $C_{11}H_{16}O_4$. Calculated %: C 62.24; H 7.59.

Condensation of 2-isopropylbutadiene with quinone. a) 2 g of diene (III) and 2 g of freshly sublimed quinone in 45 ml of alcohol were heated for 10 hours at 100°. The precipitated crystals were collected and recrystallized from a mixture of alcohol and benzene. We obtained 3.1 g of the mono adduct with m. p. 126-127°.

Found %: C 76.55, 76.48; H 7.89, 7.84. $C_{13}H_{18}O_2$. Calculated %: C 76.43; H 7.89.

b) Heating for 12 hours yielded 2.4 g of the bis adduct with m. p. 146-148° (from a mixture of ether and petroleum ether). The position of the substituents was not established.

Found %: C 79.75, 79.91; H 9.30, 9.26. $C_{23}H_{32}O_2$. Calculated %: C 79.96; H 9.38.

Condensation of 1,1,2-trimethylbutadiene (II) with crotonaldehyde. a) A mixture of 9.6 g of diene (b. p. 108-108.5°), 7.7 g (10% excess) of crotonaldehyde (b. p. 101-103°), 25 ml of petroleum ether and 0.1 g of hydroquinone was heated in a steel ampule for 12 hours at 140°. We obtained 10.8 g (65%) of a mixture of aldehydes (XII), (XIII) and (XIV) with b. p. 109-114° (20 mm), n_D^{17} 1.4786. After a second distillation, the substance had b. p. 90-92° (6 mm), n_D^{17} 1.4781-1.4809.

Found %: C 79.18, 79.04; H 10.92, 10.90. $C_{11}H_{16}O$. Calculated %: C 79.46; H 10.92.

Treatment of the mixture of aldehydes with a solution of 2,4-dinitrophenylhydrazine gave a 2,4-dinitrophenylhydrazone (about 20% of the mixture of them) with m. p. 182-182.5° (from ethyl acetate), apparently corresponding to aldehyde (XII).

Found %: C 58.97, 58.61; H 6.47, 6.42; N 15.93, 15.85. $C_{17}H_{22}O_4N_4$. Calculated %: C 58.93; H 6.40; N 16.18.

Oxidation of mixture of aldehydes (XII), (XIII) and (XIV). To freshly prepared moist silver oxide (from 18 g of silver nitrate and 250 ml of 0.5 N potassium hydroxide solution), carefully washed free from nitrate ion, was added 9.0 g of the mixture of aldehydes obtained above and a solution of 6 g of potassium hydroxide in 250 ml of 50% alcohol. The mixture was shaken at room temperature for 30 hours. The precipitate was filtered off, the filtrate evaporated to small volume in vacuum and acidified with concentrated hydrochloric acid and the liberated oil extracted with ether. The ether was removed and the residue vacuum distilled. We obtained 8.4 g (85%) of a mixture of acids (XV), (XVI) and (XVII) with b. p. 152-156° (12 mm), which partially crystallized on standing. We isolated 2.0 g (25% of the mixture) of 2,2,3,6-tetramethyl- Δ^3 -tetrahydrobenzoic acid (XV) with m. p. 126° (from dilute acetic acid).

Found %: C 72.41, 72.40; H 9.88, 9.79. $C_{11}H_{18}O_2$. Calculated %: C 72.48; H 9.95.

b) 9.6 g of diene (II) and 7.7 g of crotonaldehyde were heated at 200° for 2 hours as described above. Distillation of the reaction products in vacuum yielded 11.8 g (71%) of a mixture of aldehydes (XII), (XIII) and (XIV) with b. p. 105-108° (14 mm), n_D^{20} 1.4762-1.4782. Oxidation of this mixture by the procedure described above gave 11.0 g of a mixture of acids (XV), (XVI) and (XVII) with b. p. 122-125° (2 mm), from which we isolated 2.6 g (23% of the mixture) of acid (XV) with m. p. 125-126°.

Hydrogenation of crystalline acid (XV). 3.7 g of acid was hydrogenated in 40 ml of acetic acid over a Pt-catalyst at 50-60°. The theoretical amount of hydrogen (468 ml) was absorbed in a period of 5 hours. Vacuum distillation of the hydrogenation product gave 3.3 g of acid (XVIII) with b. p. 128-129° (2.4 mm), n_D^{20} 1.4718.

Found %: C 71.20, 71.38; H 10.56, 10.48. $C_{11}H_{20}O_2$. Calculated %: C 71.69; H 10.94.

Dehydrogenation of acid (XVIII) and subsequent oxidation. 3.0 g of acid was dehydrogenated by passage over 25% chromium oxide on aluminum oxide at 480° in a stream of nitrogen [7]. We obtained 1.05 g of hydrocarbon with b. p. 155-170° and n_D^{25} 1.5011, which was oxidized with 60 ml of 10% nitric acid under a pressure of 30 atm of nitrogen at 200° for 2 hours. We obtained 0.54 g of trimellitic acid with m. p. 224-228°, which did not depress the melting point of an authentic sample.

Dehydrogenation of mixture of acids (XV), (XVI) and (XVII) and subsequent oxidation. 11.0 g of the liquid mixture of acids, obtained after partial separation of the crystalline isomer (XV) was dehydrogenated as described above. We obtained 4 g of a mixture of hydrocarbons with b. p. 140-185°, n_D^{20} 1.5021, which were oxidized with 150 ml of 15% nitric acid under the conditions of the previous experiments. The crystals which precipitated were separated and recrystallized from hot water. We obtained 0.4 g of isophthalic acid with m. p. 330-336°, whose dimethyl ester melted at 64° and did not depress the melting point of an authentic sample.

Evaporation of the solution yielded 2.0 g of a mixture of benzenetri- and tetracarboxylic acids, which could not be separated by recrystallization and formed about 0.3 g of oil. Treatment of 1.0 g of this mixture with diazomethane gave 0.32 g of crystals with m. p. 109-110°, which were the tetramethyl ester of prehnitic acid. A mixed melting point with an authentic sample was not depressed.

Condensation of 1,1,2-trimethylbutadiene (II) with methyl acrylate and proof of structure of adducts formed. A mixture of 9.6 g of diene (b. p. 107-108°), 9.5 g (10% excess) of methyl acrylate and 0.1 g of hydroquinone was heated at 100° for 4 hours. Vacuum distillation of the reaction product yielded 12.6 g (66%) of a mixture of esters (XIX), (XX) and (XXI) with b. p. 110-115° (17 mm), b. p. 82-84° (4 mm), n_D^{20} 1.4674.

Found %: C 72.45, 72.26; H 9.99, 9.87. $C_{11}H_{18}O_2$. Calculated %: C 72.49; H 9.96.

For hydrolysis, 10 g of the mixture of adducts and 50 ml of 20% sodium hydroxide solution were boiled until solution was complete (15 hours). Vacuum distillation gave 8.3 g (86%) of a mixture of acids (XXII), (XXIII) and (XXIV) with b. p. 120-125° (3 mm), n_D^{20} 1.4878, which could not be crystallized.

Found %: C 71.43, 71.56; H 9.59, 9.57. $C_{10}H_{16}O_2$. Calculated %: C 71.38; H 9.58.

8 g of the mixture of acids obtained was hydrogenated in 60 ml of acetic acid over a Pt-catalyst at 50-60°. The theoretical amount of hydrogen (1080 ml) was absorbed after 8 hours. Vacuum distillation of the hydrogenation product yielded 7.2 g (88%) of a liquid mixture of saturated acids (XXV), (XXVI) and (XXVII) with b. p. 110-112° (2.5 mm), n_D^{20} 1.4721.

Found %: C 70.42, 70.38; H 10.43, 10.26. $C_{10}H_{10}O_2$. Calculated %: C 70.54; H 10.66.

In order to prove the structure, 6 g of this mixture of acids was passed over chromium oxide on aluminum oxide at 470-480° in a stream of nitrogen at a rate of 6-8 drops per minute. The operation was carried out twice; this gave 18 g of a mixture of hydrocarbons (b. p. 130-175°, n_D^{20} 1.5212), which were oxidized with 50 ml of 20% nitric acid under a pressure of 20 atm of nitrogen at 200° for 2 hours. The mixture of acids isolated (purified through their ammonium salts) was dissolved in 40 ml of water and carefully extracted with chloroform. Removal of the solvent and recrystallization of the crystalline residue from water yielded 0.18 g of benzoic acid with m. p. 120°, undepressed by admixture with an authentic sample. The aqueous solution was evaporated to dryness and the residue of acids treated with an ether solution of diazomethane. After removal of the ether we isolated 0.65 g of the trimethyl ester of hemimellitic acid with m. p. 101-102°, undepressed by admixtures with an authentic sample. The residual mixture of liquid methyl esters was hydrolyzed. The aqueous solution was evaporated and the residue recrystallized from water. We obtained 0.15 g of o-phthalic acid with m. p. 225-228° (with rapid heating). A mixture with an authentic sample was not depressed.

Condensation of 1,1,2-trimethylbutadiene (II) with acrylonitrile. A mixture of 13.4 g of diene (b. p. 107-108°), 8.8 g (10% excess) of acrylonitrile and 0.12 g of hydroquinone in 40 ml of benzene was heated in a steel ampule for 5 hours at 200°. Vacuum distillation yielded 15.4 g (72%) of condensation products with b. p. 98-101° (7 mm), n_D^{20} 1.4742.

Found %: C 80.26, 80.11; H 10.22, 10.08; N 9.03, 9.17. $C_{10}H_{15}N$. Calculated %: C 80.47; H 10.13; N 9.40.

Condensation of 2-isopropylbutadiene (III) with crotonaldehyde and proof and structure of adducts formed. 24 g of diene (b. p. 86-87°), 17.5 g of crotonaldehyde, 30 ml of benzene and 0.1 g of pyrogallol were heated in a steel ampule for 3 hours at 200°. Vacuum distillation of the reaction product yielded 32.6 g (80%) of a mixture of aldehydes (XIII) and (XXVIII) with b. p. 87-89° (7 mm), n_D^{20} 1.4706. From this mixture we isolated only one 2,4-dinitrophenylhydrazone (40% of mixture) with m. p. 166° (from ethyl acetate).

Found %: C 58.64, 58.75; H 6.44, 6.41; N 15.98, 16.00. $C_{17}H_{22}O_4N_4$. Calculated %: C 58.93; H 6.40; N 16.18.

The semicarbazone (30% of mixture) melted at 157-158° (from alcohol).

Found %: C 64.48, 64.41; H 9.44, 9.51; N 19.28, 19.24. $C_{13}H_{21}ON_3$. Calculated %: C 64.54; H 9.40; N 18.89.

Oxidation of 20 g of the mixture of aldehyde (XIII) and (XXVIII), as described previously, yielded 18.2 g (84%) of a mixture of acids (XVI) and (XXIX) with b. p. 146-148° (4.0 mm), n_D^{20} 1.4779. The mixture of acids obtained could not be crystallized.

Found %: C 72.84, 72.61; H 10.11, 10.17. $C_{11}H_{14}O_2$. Calculated %: C 72.48; H 9.95.

In order to prove their structure, 10 g of the mixture of acids was dehydrogenated over 20% palladium on charcoal at 310° for 4 hours. We obtained 6.5 g (80%) of a mixture of p- and m-cymenes (b. p. 172-176°, n_D^{20} 1.4912), which were oxidized by boiling with a solution of 35 g of chromium trioxide in 210 ml of 50% acetic acid and 35 ml of sulfuric acid for 5 hours. The reaction product was diluted with water and the phthalic acids liberated (5.8 g) were separated through their barium salts. We obtained 4.2 g of isophthalic acid and 1.3 g of terephthalic acid, whose dimethyl esters melted at 64-65° and 144°, respectively, and did not depress the melting points of authentic samples. Thus, the content of the meta isomer (XXVIII) in the original mixture of aldehydes was 23-25% (from the yield of terephthalic acid).

Condensation of 1,2,3-trimethylbutadiene (VI) with acrylonitrile. A mixture of 5.7 g of diene, 3.5 g of acrylonitrile, 15 ml of benzene and 0.01 g of pyrogallol was heated as described above. Distillation yielded 5.6 g (60%) of a mixture of nitriles (XXX) and (XXXI) with b. p. 113-115° (16 mm), n_D^{24} 1.4772.

Found %: N 9.12, 9.27. $C_{10}H_{15}N$. Calculated %: N 9.40.

Dehydrogenation of mixture of nitriles (XXX) and (XXXI). 6.6 g of the material was dehydrogenated over 20% palladium on charcoal at 320°. The dehydrogenation products (5.0 g) partially crystallized. We isolated 2.1 g of the nitrile of 2,3,4-trimethylbenzoic acid with m. p. 76° (from dilute alcohol).

Found %: C 82.84, 83.02; H 7.85, 7.92. $C_{10}H_{11}N$. Calculated %: C 82.71; H 7.63.

In addition we obtained 2.6 g of a liquid mixture of nitriles (n_D^{20} 1.5206), which were hydrolyzed by boiling with 25 ml of 20% potassium hydroxide for 18 hours. The reaction product was acidified with concentrated hydrochloric acid and the liberated mixture of acids (2.4 g) recrystallized from 50% alcohol. We obtained 1.8 g of 2,3,4-trimethylbenzoic acid with m. p. 186-187°, which did not depress the melting point of an authentic sample, and 0.18 g of 3,4,5-trimethylbenzoic acid with m. p. 213-216°. Oxidation of the latter with 35 ml of 10% nitric acid at 200° for 2 hours yielded an acid whose tetramethyl ester melted at 109-110° and did not depress the melting point of an authentic sample of the tetramethyl ester of 1,2,3,5-benzenetetra-carboxylic acid.

Condensation of 1,2,3-trimethylbutadiene (VI) with crotonaldehyde was carried out as described above. From 9.6 g of diene and 7 g of crotonaldehyde was obtained 12.0 g (72%) of condensation products with b. p. 72-74° (4 mm), n_D^{20} 1.4796.

Found %: C 79.44, 79.20; H 10.93, 11.02. $C_{11}H_{13}O$. Calculated %: C 79.46; H 10.92.

The 2,4-dinitrophenylhydrazone melted at 154-156° (decomp.).

Found %: C 59.00, 58.78; H 6.41, 6.2; N 16.29, 16.46. $C_{17}H_{22}O_4N_4$. Calculated %: C 58.93; H 6.40; N 16.18.

In the preparation of the semicarbazone, an oil precipitated and this could not be crystallized.

Oxidation of the mixture of aldehydes obtained with moist silver oxide by the procedure described above yielded a mixture of acids, which on standing deposited an individual crystalline acid with m. p. 112-113° in about 30% yield, though this was not studied in detail.

SUMMARY

1. Methods were developed for preparing 1,1,2-trimethyl-, 2-isopropyl and 1,2,3-trimethylbutadienes and investigations made of their diene condensation with maleic anhydride, crotonaldehyde and methyl acrylate.

2. It was established that in the condensation of 1,1,2-trimethylbutadiene with methyl acrylate and crotonaldehyde together with the normal addition products (20-40%) there were also formed the adducts of the isomeric dienes, 2-isopropyl- and 1,2,3-trimethylbutadienes, formed during the reaction.

Condensation of 1,1,2-trimethylbutadiene with maleic anhydride gave as the main product the adduct corresponding to 1,2,3-trimethylbutadiene.

3. Diene condensations of 2-isopropylbutadiene with crotonaldehyde and also of 1,2,3-trimethylbutadiene with acrylonitrile led to the formation of mixtures of adducts containing 20-25% and 5-7% of the "meta" isomers, respectively.

LITERATURE CITED

- [1] L. N. Nazarov and M. V. Mavrov, J. Gen. Chem. 28, 3061 (1958).*
- [2] Y. R. Naves and P. Ardizio, Helv. Chim. Acta, 31, 2252 (1948).
- [3] Y. R. Naves and P. Ardizio, Helv. Chim. Acta, 31, 2256 (1948).
- [4] Alder, Fortschritte der Chemi organischer Naturstoffe, Wien, 10, 1 (1953).
- [5] L. N. Nazarov, L. L. Kotlyarevskii and V. F. Ryabchenko, J. Gen. Chem. 23, 1900 (1953).*
- [6] C. S. Marvel, R. L. Meyers, and J. H. Saunders, J. Am. Chem. Soc. 70, 1694 (1948).
- [7] J. P. Ferrin, T. B. Tom, et al, J. Org. Chem. 19, 923 (1954).

Received March 3, 1958.

*Original Russian pagination. See C.B. Translation.

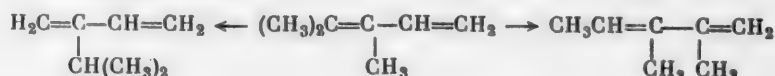
DIENE CONDENSATIONS OF GEM-SUBSTITUTED BUTADIENES

III. 1,1-DIMETHYL-2-ISOPROPYLBUTADIENE

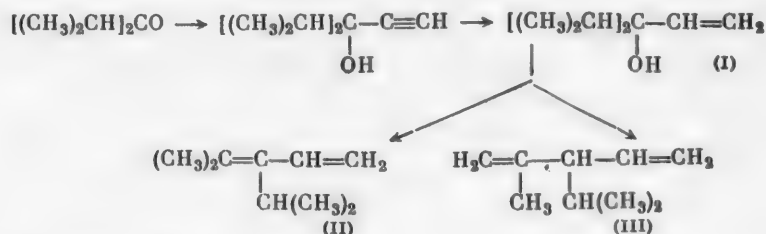
I. N. Nazarov* and M. V. Mavrov

Institute of Organic Chemistry, Academy of Sciences, USSR

It was previously shown [1] that in diene condensations of 1,1,2-trimethylbutadiene with unsymmetrical dienophils, together with the normal products corresponding to this diene (20-40%), there were also produced adducts of the isomeric dienes (1,2,3-trimethyl- and 2-isopropylbutadienes), formed during the reaction as a result of isomerization of the original diene.

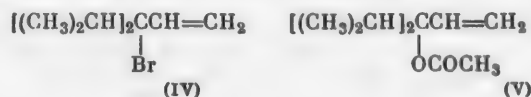


In the course of a systematic study of diene condensations with geminal dienes, we also investigated the behavior of another representative of this type of diene, 1,1-dimethyl-2-isopropylbutadiene-1,3 (II). To synthesize this diene, we studied the dehydration of diisopropylvinylcarbinol (I), obtained in 60% yield by the condensation of diisopropyl ketone with acetylene under pressure, with subsequent partial hydrogenation of the triple bond.



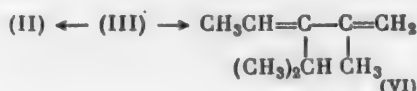
It was to be expected that the dehydration of diisopropylvinylcarbinol (I) would form only one product, 1,1-dimethyl-2-isopropylbutadiene-1,3 (II); however, it was found that the dehydration of the alcohol was much more complex. When dehydrated by distillation over potassium bisulfite and also over 20% zirconium dioxide on pumice in the vapor phase, carbinol (I) gave a mixture (1:3) of 1,1-dimethyl-2-isopropylbutadiene-1,3 (II) and 2-methyl-3-isopropylpentadiene-1,4 (III), which could be separated by fractional distillation on a column of 39 theoretical plates.

An attempt to direct the cleavage towards the gem-substituted diene by dehydrobromination of the bromide (IV) and also by pyrolysis of the acetate (V) did not lead to the desired results. In these cases also, the amount of the required diene in the mixture formed was only 20%.



* Deceased.

The position of the double bonds in the dienes (II) and (III) was proved by studying their oxidation products. Ozonization of 2-methyl-3-isopropylpentadiene-1,4 (III) gave formaldehyde (in the form of the dimedone derivative) in 30% yield on one methylene group, while oxidation of 1,1-dimethyl-2-isopropylbutadiene (II) with potassium permanganate at 0° yielded acetone and isobutyric acid. However, the fraction with b. p. 130-132.5°, corresponding to the required diene (II), evidently contained a certain amount of another possible isomer, 1,3-dimethyl-2-isopropylbutadiene-1,3 (VI), which could be formed by isomerization of hydrocarbon (III).

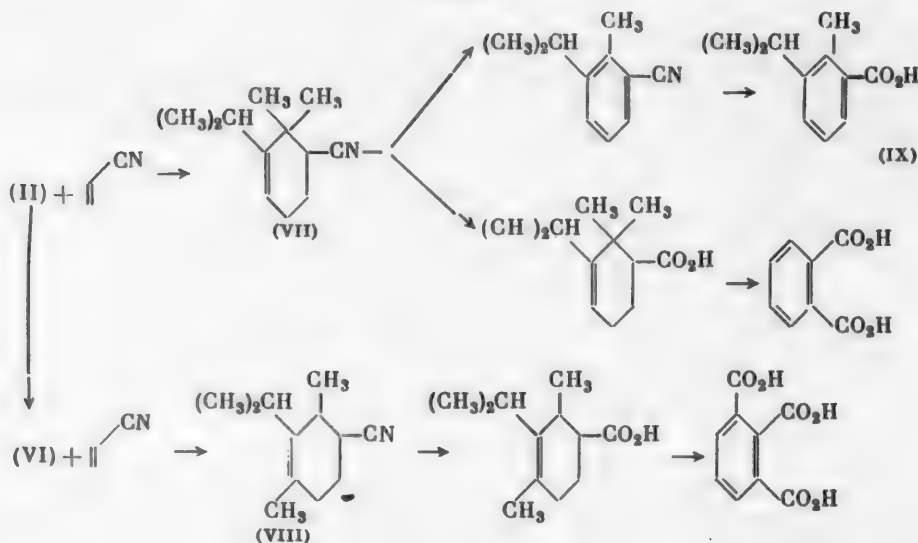


This was indicated, for example, by variations in the position of the UV absorption maximum at λ_{max} 230-234 m μ between various fractions of the diene with b. p. 130.0-132.5° and we were unable to separate these isomers on a column of 39 theoretical plates.

The fact that the dehydration of unsaturated alcohols [1,2] proceeds preferentially towards the formation of isomeric forms of dienes, which are less probable according to the generally accepted elimination rules, evidently indicates the lower energetic stability of gem-substituted dienes. In its turn, this throws the light on their behavior in diene synthesis reactions, which proceed under comparatively drastic conditions and as a result of this, the unstable geminal dienes are isomerized into the energetically favored isomeric forms.

For studying the condensations of 1,1-dimethyl-2-isopropylbutadiene (II), as previously [3], we chose maleic anhydride, acrylonitrile, methyl acrylate and crotonaldehyde as the dienophils.

Scheme 1



On the basis of previously studied diene condensations of gem-substituted butadienes (1, 3), in this case also the formation of adducts corresponding to the isomeric form of the diene (VI) was expected.

It was found that when diene (II) was heated with acrylonitrile at 200° for 5 hours, a 50% yield of a mixture of the cyclic nitriles (VII) and (VIII) (scheme 1) was formed.

Dehydrogenation of the mixture of adducts (VII) and (VIII) over chromium oxide on aluminum oxide at 490-500° gave about a 50% yield of aromatic and unsaturated nitriles, which were hydrolyzed by heating in an autoclave at 140° for 30 hours with alcoholic potassium hydroxide. On distillation, the mixture of acids formed gave a 15-20% yield of crystalline 2-methyl-3-isopropylbenzoic acid (IX), whose structure was proved by its

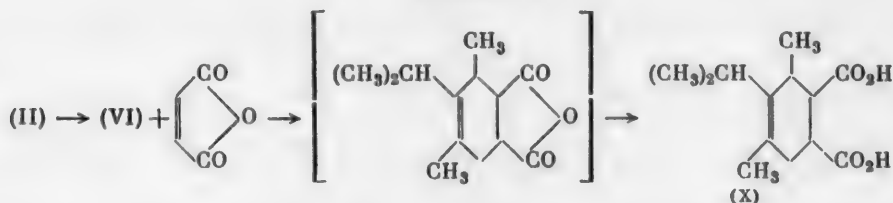
conversion into hemimellitic acid. This rigidly proved that the mixture of adducts contained the diene synthesis product corresponding to the condensation of acrylonitrile with diene (II).

The liquid portion of the mixture of acids remaining after isolation of the acid (IX) was again dehydrogenated over chromium oxide on aluminum oxide at 480°. After oxidation with dilute nitric acid under pressure, the mixture of hydrocarbons thus obtained gave a mixture of *o*-phthalic and hemimellitic acids in a ratio of approximately 1:4. The fact that a considerable amount of the latter was isolated in this case unequivocally shows that the original adduct contained the isomeric nitrile (VIII), formed from the isomeric diene (VI).

The condensation of diene (II) with methyl acrylate proceeded similarly with the formation of a mixture of adducts, which yielded a liquid mixture of the corresponding acids on hydrolysis. The structures of the latter were established as indicated above, by their dehydrogenation over chromium oxide on aluminum oxide with simultaneous decarboxylation and oxidation of the aromatic hydrocarbons obtained. This yielded *o*-phthalic and hemimellite acids in a ratio of approximately 1:4.

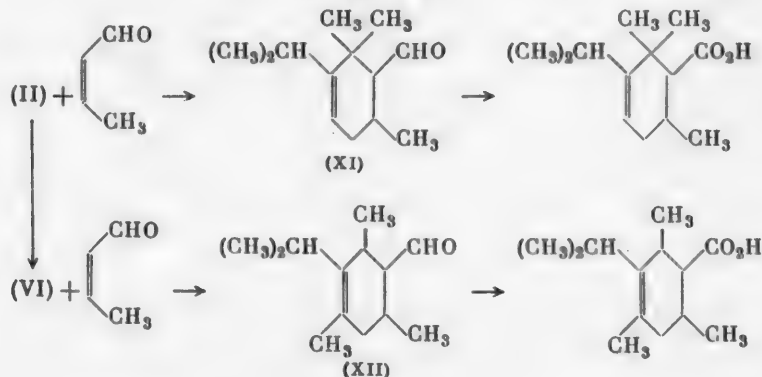
When equimolecular amounts of diene (II) and maleic anhydride were heated in benzene solution at 100°, the addition product was formed in only 5-8% yield. If the same reaction was performed without solvent with a 3-5-fold excess of the dienophile, then after hydrolysis, a 70% yield of an individual acid was formed, and this was apparently 3,5-dimethyl-4-isopropyl- Δ^4 -tetrahydrophthalic acid (X), formed as a result of diene condensation with the isomeric form of the diene (VI) (scheme 2).

Scheme 2



A condensation product of diene (II) with crotonaldehyde was formed with great difficulty. The best yield (40%) was obtained by heating a mixture of the components in petroleum ether for 4.5 hours at 200°. In all probability, the adduct was a mixture of at least two isomeric aldehydes, (XI) and (XII), which gave a mixture of crystalline and liquid acids when oxidized with moist silver oxide; however, the structures of the latter were not studied more closely (scheme 3).

Scheme 3



Thus, the results obtained show that 1,1-dimethyl-2-isopropylbutadiene-1,3, like 1,1,2-trimethyl- and 1,1,4-trimethylbutadienes, partially undergo diene synthesis without isomerization, forming mainly the adduct of *ortho* orientation.

EXPERIMENTAL

Diisopropylvinylcarbinol (I). 280 g of diisopropylethynylcarbinol (b. p. 163-165°, n_D^{20} 1.4502), obtained by condensation of diisopropyl ketone with acetylene under pressure [4], was selectively hydrogenated with 0.5 g of 2% palladium on calcium carbonate. Distillation of the reaction product yielded 260 g of carbinol (I).

B. p. 162-164°, 94-95° (77 mm), n_D^{20} 1.4446, d_4^{20} 0.8497, MR_D 44.50; calc. 44.82.

Found %: C 75.67, 75.53; H 12.82, 12.70. $C_9H_{18}O$. Calculated %: C 75.99; H 12.75.

Dehydration of diisopropylvinylcarbinol. a) **Over zirconium dioxide.** The dehydration of 213 g of carbinol (I) over 20% zirconium dioxide on pumice at 305-310° and an throughput rate of 0.7-0.8 ml/min yielded 146 g (80%) of a mixture of hydrocarbons (II) and (III) with b. p. 122-134°, n_D^{22} 1.4401 and 23 g of the original carbinol with b. p. 150-165°. Distillation over sodium of 39 theoretical plates yielded two main fractions. • The first had b. p. 124-125.5° (82 g) and was 2-methyl-3-isopropylpentadiene-1,4 (III) and the 2nd had b. p. 130-132.5° (26 g) and was mainly 1,1-dimethyl-2-isopropylbutadiene-1,3 (II).

After a second distillation, hydrocarbon (III) had the following constants: b. p. 124.6-125° (738 mm), n_D^{20} 1.4328, d_4^{20} 0.7577, MR_D 42.58; calc. 42.83.

Found %: C 87.20, 86.98; H 13.05, 13.14. C_9H_{16} . Calculated %: C 87.01; H 12.99.

When hydrogenated catalytically over PtO_2 , this hydrocarbon absorbed 2 moles of hydrogen.

In an attempt to condense 2-methyl-3-isopropylpentadiene-1,4 (III) with maleic anhydride (100°, 15 hours), it was recovered unchanged.

For ozonization, ozonized oxygen (ozone concentration 5%) was passed into a solution of 2 g of diene (III) in 60 ml of 95% acetic acid with cooling in ice and salt for 4 hours. To 15 ml of the ozonide solution was added 0.8 g of zinc dust and 15 ml of acetic acid. The mixture was stirred at 60-65° for 1.5 hours and then after removal of the zinc dust, the formaldehyde was determined as the dimedone derivative. We obtained 0.8 g of material with m. p. 189-190°, which did not depress the melting point of an authentic sample. The total yield of formaldehyde was 30% on one methylene group.

After a second distillation, the 2nd fraction had the following constants:

b. p. 131.7-132.2° (760 mm), n_D^{20} 1.4448, d_4^{20} 0.7504, MR_D 44.02; calc. 42.83.

Found %: C 86.80, 87.10; H 13.10, 12.90. C_9H_{16} . Calculated %: C 87.01; H 12.99.

The UV spectrum of this fraction showed λ_{max} 232 m μ , while other fractions from this distillation had λ_{max} varying from 230 to 234 m μ .

Oxidation of 5.0 g of this diene with potassium permanganate gave 1.0 g of acetone and 2.0 g of isobutyric acid. The 2,4-dinitrophenylhydrazone of the acetone and the p-bromophenyl ester of the isobutyric acid did not depress the melting points of authentic samples.

b) **Over potassium bisulfite.** Heating a mixture of 71 g of carbinol (I) and 8 g of potassium bisulfite to 165° yielded 42.5 g (about 70%) of the mixture of hydrocarbons (II) and (III) with b. p. 126-135°, n_D^{28} 1.4402, containing, according to data from distillation on a column, 17.3 g of unconjugated diene (III) and 11.6 g of diene (II) with b. p. 131-132.5°, n_D^{27} 1.4389.

3-Isopropyl-4-methyl-3-bromopentene (IV). To a solution of 45 g of freshly distilled phosphorus tribromide in 50 ml of absolute benzene, 71 g of carbinol (I) in 40 ml of benzene was added with cooling and vigorous stirring at such a rate that the reaction temperature did not exceed 5°. Vacuum distillations of the reaction product yielded 86 g (85%) of bromide (IV) with b. p. 68-70° (10 mm), n_D^{20} 1.4796.

Found %: Br 38.91, 38.68. $C_9H_{17}Br$. Calculated %: Br 38.94.

Dehydrobromination of bromide (IV). Heating 100 g of bromide (IV) to 190° with 55 g of solid 85% potassium hydroxide yielded 48 g (80%) of a mixture of hydrocarbons with b. p. 124-132° and n_D^{18} 1.4401, and

• In this and subsequent experiments, the intermediate fractions were 12-16% of the total amount of hydrocarbons taken for distillation.

fractional distillation of this yielded 23.2 g of diene (III) and 8.1 g of geminal diene (II).

Acetate of diisopropylvinylcarbinol (V). 142 g of carbinol (I) was added to a boiling solution of acetic anhydride (306 g) over a period of 2 hours. The mixture was boiled for a further 7 hours, cooled and poured into an ice-cooled saturated solution of sodium carbonate. Vacuum distillation of the reaction product gave 152 g of acetate (V).

B. p. 134-139° (100 mm), 121-123° (53 mm), n_D^{20} 1.4397.

Found %: C 71.76, 71.84; H 10.82, 10.83. $C_{11}H_{20}O_2$. Calculated %: C 71.70; H 10.94.

Pyrolysis of acetate (V). 92 g of the acetate was passed through a quartz tube packed with pieces of quartz (tube, 16 mm in diameter, length of bed, 50 cm) at 500° in a stream of nitrogen at a rate of 1.1 ml/min. Working up in the usual way yielded 42 g of the starting acetate with b. p. 114-120° (50 mm), n_D^{21} 1.4383 and 24.8 g (38%) of a mixture of hydrocarbons (II) and (III) with b. p. 126-132°, n_D^{21} 1.4396, whose ratio was approximately 1:4 according to fractional distillation on a column.

Condensation of 1,1-Dimethyl-2-isopropylbutadiene with Acrylonitrile.

A mixture of 24.8 g of diene (II), 10.6 g of acrylonitrile, 30 ml of petroleum ether and 0.02 g of hydroquinone was heated in a steel ampule at 200° for 5 hours. Vacuum distillation of the reaction product yielded 20.0 g (60%) of a mixture of nitriles (VII) and (VIII), with b. p. 131-133° (16 mm), n_D^{22} 1.4768-1.4791, 5.6 g res.

Found %: C 81.55, 81.69; H 10.80, 10.81. $C_{12}H_{13}N$. Calculated %: C 81.30; H 10.80.

Proof of structure of adducts (VII) and (VIII). 18 g of the mixture of nitriles obtained above was dehydrogenated over chromium oxide on aluminum oxide (tube diameter, 12 mm, bed length, 20 cm) at 490-500° in a stream of nitrogen at a rate of 1 drop every 4-6 seconds. After two passes, the dehydrogenation product was distilled; we obtained 2.4 g of a hydrocarbon fraction (b. p. 154-186°, n_D^{21} 1.4986) and 9.0 g (50%) of partially aromatized nitriles (b. p. 90-128° at 18 mm, n_D^{21} 1.5132-1.5150) which were hydrolyzed by heating with alcoholic potassium hydroxide (10 g of 85% potassium hydroxide in 10 ml of methanol and 1 ml of water) in a steel ampule at 140° for 30 hours. The reaction product was diluted with 5 ml of water and extracted with ether. The aqueous layer was acidified with concentrated hydrochloric acid (to congo) and the oil thus liberated was extracted with ether. Vacuum distillation yielded 8.5 g of a mixture of acids with b. p. 148-153° (4 mm), which partially crystallized. We isolated 1.8 g of crystalline 2-methyl-3-isopropylbenzoic acid (IX) with m. p. 148° (from 30% methanol).

Found %: C 73.97, 73.94; H 7.86, 7.77. M (titrated) 176, 173. $C_{11}H_{14}O_2$. Calculated %: C 74.12; H 7.91. M 178.

The residue (6.6 g) was apparently a mixture of aromatic and unsaturated acids, which we were unable to crystallize.

Oxidation of 2-methyl-3-isopropylbenzoic acid (IX). 0.4 g of acid (m. p. 148°) was oxidized with 25 ml of 10% nitric acid under a nitrogen pressure of 20 atm at 200° for 2 hours. The normal processing yielded 0.3 g of hemimellitic acid with m. p. 195-197°, which did not depress the melting point of an authentic sample. Its dimethyl ester melted at 102° and did not depress the melting point of an authentic sample.

Dehydrogenation of the liquid mixture of acid and subsequent oxidation. The residual acids (6.6 g) after separation of acid (IX) was again dehydrogenated over chromium oxide on aluminum oxide at 480° in a stream of nitrogen for 3 hours. We obtained 2.3 g of a hydrocarbon with b. p. 160-200°, n_D^{19} 1.5058. This was combined with the hydrocarbon (4.7 g) obtained previously in the oxidation of the mixture of nitriles (VII) and (VIII) and oxidized with 160 ml of 15% nitric acid under a pressure of 30 atm of nitrogen at a temperature of 200° for 2.5 hours. Processing in the normal way and purification through the ammonium salts gave 3.2 g of a mixture of aromatic acids. Treatment of them with an ether solution of diazomethane yielded 1.6 g of the trimethyl ester of hemimellitic acid with m. p. 102°, which did not depress the melting point of an authentic sample. Hydrolysis of the residual mixture of liquid esters and recrystallization from hot water gave about 0.3 g of o-phthalic acid with m. p. 190-191° (sealed capillary), undepressed by admixture with an authentic sample.

Condensation of 1,1-Dimethyl-2-isopropylbutadiene with Crotonaldehyde

12.4 g of diene (II), 7.7 g of crotonaldehyde (b. p. 101-103°), 30 ml of petroleum ether and 0.01 g of hydroquinone were heated together in a steel ampule at 200° for 4.5 hours. Vacuum distillation of the reaction product yielded 7.7 g (40%) of a mixture of aldehydes (XI) and (XII) with b. p. 83-86° (3 mm), n_D^{20} 1.4718-1.4802. No satisfactory analysis of the material was obtained.

Treatment of the mixture of aldehydes with 2,4-dinitrophenylhydrazine solution yielded a 2,4-dinitrophenylhydrazone (35%) with m. p. 161° (from alcohol).

Found %: C 60.80, 60.60; H 6.94, 6.92; N 15.03, 15.31. $C_{19}H_{26}O_4N_4$. Calculated %: C 60.96; H 6.99; N 14.97.

Oxidation of mixture of aldehydes. To freshly prepared moist silver oxide (from 8.8 g of silver nitrate and 100 ml of 0.5 N potassium hydroxide solution) was added 2.5 g of potassium hydroxide and 5 g of the mixture of aldehydes (b.p. 83-86° at 3 mm) in 200 ml of 50% alcohol. The mixture was shaken at room temperature for 6 hours and then at 55-60° for 5 hours. The precipitate was filtered off and the solution evaporated to small volume in vacuum and extracted with ether to remove unreacted material (0.2 g). The residue was acidified with concentrated hydrochloric acid (to congo) and the liberated oil extracted with ether; the ether extract was dried with magnesium sulfate and distilled. We obtained 3.1 g of a mixture of acids with b. p. 147-150° (5 mm), which crystallized on standing. We isolated 0.6 g of a discrete crystalline acid, melting at 108-108.5°, which was not studied further.

Found %: C 74.02, 74.00; H 10.55, 10.63. M (titrated) 204, 205. $C_{19}H_{22}O_2$. Calculated %: C 74.24; H 10.54. M 210.

Condensation of 1,1-Dimethyl-2-isopropylbutadiene with Methyl Acrylate

A mixture of 5 g of diene (II), and 3.8 g (10% excess) of methyl acrylate in the presence of hydroquinone was heated in a steel ampule for 7 hours. Distillation of the reaction mixture in vacuum yielded 5.4 g (64%) of a condensation product with b. p. 94-97° (2 mm), n_D^{20} 1.4684.

Found %: C 74.79, 74.83; H 10.55, 10.70. $C_{19}H_{22}O_2$. Calculated %: C 74.24; H 10.54.

Investigation of condensation products. 5.0 g of the material (b. p. 94-97° at 4 mm) was boiled for 8 hours with 35 ml of 12% sodium hydroxide solution. The reaction product was acidified with concentrated hydrochloric acid and extracted with ether. The ether was removed and the residue vacuum distilled. We obtained 3.9 g of a mixture of liquid acids with b. p. 143-145° (4 mm), n_D^{20} 1.4848.

Found %: C 73.42, 73.52; H 10.22, 10.30. $C_{12}H_{20}O_2$. Calculated %: C 73.42; H 10.27.

6 g of the mixture of unsaturated acids obtained in this way was passed over 20% chromium oxide on aluminum oxide at 470-480° in a stream of nitrogen at a rate of 6-8 drops per minute. The operation was repeated twice. We obtained 1.6 g of a mixture of hydrocarbons with b. p. 160-196° and n_D^{22} 1.5032, which was oxidized with 80 ml of 10% nitric acid under a pressure of 25 atm of nitrogen at 200° for 2 hours. Processing in the usual way yielded 1 g of a mixture of aromatic acids and separation of these through their methyl esters by the procedure described above yielded 0.6 g of hemimellitic and 0.14 g of o-phthalic acids, which did not depress the melting points of authentic samples.

Condensation of 1,1-Dimethyl-2-isopropylbutadiene with Maleic Anhydride

a) In a condensation in a benzene solution, part of the diene was recovered. An insignificant amount of a crystalline acid, which was not examined more closely, was isolated.

b) Condensation without solvent. In the presence of hydroquinone, 3.0 g of diene and 7.2 g (3-fold excess) of maleic anhydride were heated at 100° for 16 hours. The reaction product was hydrolyzed with 40% potassium hydroxide solution and extracted with benzene. The aqueous layer was acidified with concentrated hydrochloric acid. The crystals liberated were collected by filtration, washed with hot water and recrystallized from a mixture of ether and petroleum ether (1:5). We obtained 4.2 g (70%) of acid (X) with m. p. 138-139°, whose structure was not proven.

Found % C 64.99, 65.15; H 8.25, 8.14. $C_{11}H_{20}O$. Calculated % C 64.94; H 8.38.

SUMMARY

1. It was shown that catalytic dehydration of diisopropylvinylcarbinol, dehydrobromination of the bromide and pyrolysis of the acetate of this alcohol gave a mixture of 1,1-dimethyl-2-isopropylbutadiene-1,3 and 2-methyl-3-isopropylpentadiene-1,4, containing only 20-35% of the geminal diene.

2. A study was made of the diene condensations of 1,1-dimethyl-2-isopropylbutadiene. In the condensation with acrylonitrile and methyl acrylate, it was shown that together with the normal product of diene synthesis (to 35%), there was also formed the adduct corresponding to the isomeric diene, 1,3-dimethyl-2-isopropylbutadiene-1,3.

LITERATURE CITED

- [1] L. N. Nazarov and M. V. Mavrov, J. Gen. Chem. 29, 1148 (1959).*
- [2] L. N. Nazarov and M. V. Mavrov, Bull. Acad. Sci. USSR, Div. Chem. Sci. 1958, 365.*
- [3] L. N. Nazarov and M. V. Mavrov, J. Gen. Chem. 28, 3061 (1958).*
- [4] L. N. Nazarov, L. L. Kotlyarevskii and V. F. Ryabchenko, J. Gen. Chem. 23, 1900 (1953).*

Received March 3, 1958

*Original Russian pagination. See C.B. Translation.

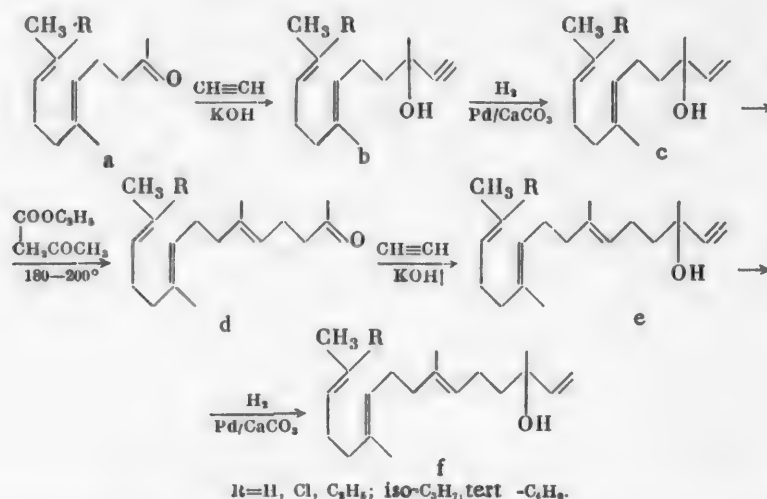
SYNTHESIS OF ANALOGS OF NEROLIDOL, FARNESYLACETONE AND GERANYLLINALOOL

I. N. Nazarov,* S. M. Makin, V. B. Mochalin, O. A. Shavrygina,
and D. V. Nazarova

Lomonosov Institute of Fine Chemical Technology, Moscow

In recent years, investigations have been made in our laboratories on methods of synthesizing isoprenoid compounds. The successive repetition of the condensation of ketones with acetylene, selective hydrogenation of the acetylene alcohols into vinyl alcohols and conversion of tertiary vinyl and acetylene alcohols into unsaturated ketones by three different methods was used to prepare methylheptenone, dehydrolinalool, geranylacetone, pseudoionone, pseudoionone and their analogs [1, 2]. Nerolidol, farnesylacetone and geranyllinalool were also obtained by the use of these methods [3].

In the present work we made a detailed investigation of the preparation of isoprenoid alcohols and ketones, analogs of nerolidol, farnesylacetone, geranyllinalool and intermediate compounds by the following general scheme:

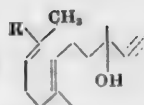


Analog of geryanylacetone (a) were condensed with acetylene by the procedure developed in our laboratory [4]; the reaction was performed in a steel reactor of 2 or 6 liters capacity at 0-20° in the presence of powdered potassium hydroxide and under an acetylene pressure of 5-10 atm. The yield of tertiary acetylene alcohols (b) was 80-85%. Until recently, such condensations were accomplished by a quite laborious and complex process, namely, by the action of sodium or lithium acetylide in liquid ammonia solution [5, 6]. All the analogs of dehydronerolidol (b) we synthesized are presented in Table 1.

* Deceased

TABLE 1

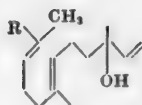
Analog of Dehydronerolidol



Compound No.	R	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D		Found (%)		Calculated (%)		Yield (in %)
					found	calc.	C	H	C	H	
(I)	H	87—89° (2)	1.4760	0.8910	65.20	65.38	81.34, 81.37	10.78, 10.70	81.55	10.68	81
(II)	Cl	108—110 (1)	1.4893	0.9867	70.47	70.25	69.74, 69.94	8.68, 8.83	69.89	8.73	81
(III)	C ₂ H ₅	122—123 (1)	1.4800	0.8926	74.58	74.60	82.04, 81.85	11.33, 11.30	81.95	11.19	71
(IV)	Iso-C ₃ H ₇	132—133 (2)	1.4775	0.8884	79.08	79.22	82.09, 82.43	11.11, 11.39	82.20	11.36	82
(V)	Tert-C ₄ H ₉	109—111 (0.08)	1.4791	0.8828	84.18	84.08	82.45, 82.61	11.44, 11.65	82.44	11.45	82

TABLE 2

Analog of Nerolidol



Compound No.	R	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D		Found (%)		Calc. (%)		Yield (in %)
					found	calc.	C	H	C	H	
(VI)	H	86—88° (2)	1.4744	0.8747	66.73	66.87	80.79, 80.64	11.65, 11.74	80.77	11.54	95
(VII)	Cl	108—109 (1)	1.4872	0.9729	71.68	71.84	69.37, 68.99	9.56, 9.64	69.28	9.48	92
(VIII)	C ₂ H ₅	121—122 (1)	1.4790	0.8804	76.14	76.20	81.56, 81.62	11.68, 11.69	81.29	11.94	95
(IX)	Iso-C ₃ H ₇	130—131 (2)	1.4762	0.8754	80.70	80.82	81.61, 81.43	11.86, 12.38	81.53	12.08	96
(X)	Tert-C ₄ H ₉	108—110 (0.15)	1.4778	0.8720	85.40	85.44	81.66, 81.69	12.22, 12.18	81.75	12.19	92

In our laboratory it was shown that unsubstituted acetylene alcohols are hydrogenated quite selectively in the presence of palladium on calcium carbonate to give an almost quantitative yield of the corresponding vinyl alcohols [7]. The hydrogenation of the acetylene alcohols we obtained, analogs of dehydronerolidol (b), proceeded similarly in the presence of Pd/CaCO₃.

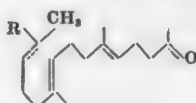
The hydrogenation reaction was controlled by means of a test with an ammonia solution of silver oxide. After the addition of exactly one molecule of hydrogen to the acetylene alcohol, the test for acetylene hydrogen became negative.

The sensitivity of the acetylene test was determined in special control experiments and was about 0.3%. The analogs of nerolidol, obtained by partial hydrogenation of acetylene alcohols (b) in the presence of Pd/CaCO₃, are presented in Table 2.

From the literature it is known that when alcohols of the allyl type are heated with acetoacetic ester in the presence of alkaline catalysts, γ , δ -unsaturated ketones are formed [8]. In recent years, this reaction has been studied in detail in our laboratory. It was found that the reaction between tertiary vinyl alcohols and acetoacetic ester proceeded best at 160–190° without any catalysts. Methylheptenone, geranylacetone and their analogs were obtained in this way [1, 2]. In the present work we used this method for the synthesis of analogs of farnesylacetone (d). When the analogs of nerolidol (Table 2) described above were heated with acetoacetic ester at 180–200°, we obtained analogs of farnesylacetone (d) and during the reaction, almost theoretical amounts of alcohol and carbon dioxide were liberated. It was not possible to obtain the chlorine-containing analog of farnesylacetone by heating the tertiary carbinol (VII) with acetoacetic ester since such chlorine-containing compounds were found to be unstable to heating. The ketones obtained (d) are presented in Table 3.

TABLE 3

Analog of Farnesylacetone



Compound No.	R	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D		Found (%)		Calc. (%)		Yield (in %)
					found	calc.	C	H	C	H	
(XI)	H	124–127° (2)	1.4770	0.8849	79.19	79.32	82.31, 82.41	11.31, 11.27	82.26	11.30	60
(XII)	C_2H_5	132–133 (0.1)	1.4803	0.8884	88.42	88.55	82.76, 82.67	11.74, 11.71	82.55	11.67	58.4
(XIII)	Iso- C_3H_7	135–136 (0.1)	1.4791	0.8849	93.10	93.17	82.65, 82.46	11.87, 11.85	82.73	11.80	51
(XIV)	Tert- C_4H_9	135–137 (0.02)	1.4808	0.8814	98.05	97.79	83.12, 83.20	11.78, 11.97	82.90	11.84	60

We then condensed the analogs of farnesylacetone synthesized (d) with acetylene. The tertiary acetylene alcohols (e) obtained in this way were partially hydrogenated over Pd/CaCO₃ and converted into analogs of geranylinalool (f). The acetylene synthesis and selective hydrogenation were carried out in the usual way as described above for analogs of dehydronerolidol (b) and nerolidol (c). The alcohols obtained are given in Tables 4 and 5.

EXPERIMENTAL

2-Chloro-6,10-dimethyldodecadien-2,6-yn-11-ol-10 (II). In a 2 liter steel reactor was placed 600 ml of dry ether and 50 g of powdered potassium hydroxide. With vigorous stirring, the mixture was saturated with acetylene at -5° and a pressure of 8 atm, which was maintained during the whole experiment. Over a period of 40 minutes, 100 g of 2-chloro-6-methylundecadien-2,6-one-10 was introduced into the reactor, after which the reaction mixture was stirred for a further 2 hours. At the end of the experiment, the temperature slowly rose to 20°. The acetylene pressure was then released and 200 ml of water added to the mixture with stirring. The ether layer was separated and the aqueous layer extracted with ether. The combined ether extracts were neutralized with carbon dioxide and dried magnesium sulfate. Distillation yielded 90.7 g of 2-chloro-6,10-dimethyldodecadien-2,6-yn-11-ol-10 (II).

In a similar way we prepared 6,10-dimethyldodecadien-2,6-yn-11-ol-10 (I), 3,7,11-trimethyltridecadien-3,7-yn-12-ol-11 (III), 2,3,7,11-tetramethyltridecadien-3,7-yn-12-ol-11 (IV) and 2,2,3,7,11-pentamethyltridecadien-3,7-yn-12-ol-11 (V) (see Table 1).

2-Chloro-6,10-dimethyldodecatrien-2,6,11-ol-10 (VII). 50 g of 2-chloro-6,10-dimethyldodecadien-

TABLE 4

Tertiary Acetylene Alcohols



Compound No.	R	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR _D		Found (%)		Calc. (%)		Yield (in %)
					found	calc.	C	H	C	H	
(XV)	H	146—148° (2.5)	1.4863	0.8909	88.34	88.00	82.73	82.81	83.21	10.95	85
(XVI)	C ₂ H ₅	146—147 (0.11)	1.4877	0.8959	97.24	97.30	83.49	83.24	83.33	11.33	87
(XVII)	Tert -C ₄ H ₉	141—144 (0.06)	1.4879	0.8886	106.90	106.53	83.86	83.78	83.63	11.51	87

TABLE 5

Analogues of Geranylinalool



Compound No.	R	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR _D		Found (%)		Calc. (%)		Yield (in %)
					found	calc.	C	H	C	H	
(XVIII)	H	149—151° (3)	1.4819	0.8784	89.53	89.59	82.90	82.82	82.60	11.66	92
(XIX)	C ₂ H ₅	145—146 (0.11)	1.4871	0.8874	98.71	98.83	82.99	83.01	82.82	11.92	95
(XX)	Tert -C ₄ H ₉	138—141 (0.01)	1.4868	0.8820	108.21	108.07	82.92	83.03	83.13	12.05	85

2,6-yn-11-ol-10 (II) was hydrogenated in the presence of 0.5 g of Pd/CaCO₃. After the absorption of 5.41 liters of hydrogen (19°, 730 mm) the hydrogenation was stopped. A test for acetylene hydrogen was negative. The catalyst was filtered off and the product vacuum distilled. We obtained 46 g of 2-chloro-6,10-dimethyldodecatrien-2,6, 11-ol-10 (VII).

Similarly we prepared 6,10-dimethyldodecatrien-2,6-11-ol-10 (VI), 3,7,11-trimethyltridecatrien-3,7,12-ol-11 (VIII), 2,3,7,11-tetramethyltridecatrien-3,7,12-ol-11 (IX) and 2,2,3,7,11-pentamethyltridecatrien-3,7,12-ol-11 (X) (see Table 2).

2,2,3,7,11-Pentamethylhexadecatrien-3,7,11-one-15 (XIV). A mixture of 185 g of 2,2,3,7,11-pentamethyltridecatrien-3,7,12-ol-11 (X) and 182 g of acetoacetic ester was heated in a Favorski flask with a 30 cm high reflux head at 180-200° for 5 hours until the evolution of carbon dioxide ceased (45 ml of alcohol distilled over during this time). The reaction product was dissolved in ether, washed three times with 5% sodium bicarbonate solution and dried with magnesium sulfate. Two vacuum distillations yielded 128 g of 2,2,3,7,11-pentamethylhexadecatrien-3,7,11-one-15 (XIV).

The semicarbazone had m. p. 87-89° (from alcohol).

Found %: N 11.74, 11.92. C₂₂H₃₉ON₃. Calculated %: N 12.03.

In a similar way we prepared 6,10-dimethylpentadecatrien-2,6,10-one-14 (XI), 3,7,11-trimethylhexadecatrien-3,7,11-one-15 (XII) and 2,3,7,11-tetramethylhexadecatrien-3,7,11-one-15 (XIII)* (see Table 3).

3,7,11,15-Tetramethylheptadecatrien-3,7,11-yn-16-ol-15 (XVI). Into a 2 liter steel reactor was placed 1000 ml of dry ether and 50 g of powdered potassium hydroxide. With vigorous stirring and cooling to -10°, the mixture was saturated with acetylene at 8 atm pressure, which was maintained during the whole experiment. Over a period of 35 minutes, 30 g of 3,7,11-trimethylhexadecatrien-3,7,11-one-15 (XII) was introduced into the reactor from a dropping funnel. The mixture was stirred for 1 hour at -10° and for 2 hours at room temperature. The acetylene pressure was released and the mixture processed in the usual way. We obtained 28.2 g of 3,7,11,15-tetramethylheptadecatrien-3,7,11-yn-16-ol-15 (XVI).

Similarly we obtained 6,10,14-trimethylhexadecatrien-2,6,10-yn-15-cl-14 (XV) and 2,2,3,7,11,15-hexamethylheptadecatrien-3,7,11-yn-16-ol-15 (XVII) (see Table 4).

3,7,11,15-Tetramethylheptadecatetraen-3,7,11,16-ol-15 (XIX). 26.5 g of the acetylene alcohol (XVI) was dissolved in 50 ml of methyl alcohol and hydrogenated in the presence of 0.1 g of 5% Pd/CaCO₃. After 2.5 hours, the theoretical amount of hydrogen had been absorbed. The hydrogenation was stopped, the catalyst filtered off and the product vacuum distilled. We obtained 25.2 g of 3,7,11,15-tetramethylheptadecatetraen-3,7,11,16-ol-15 (XIX).

Similarly we prepared 6,10,14-trimethylhexadecatetraen-2,6,10,15-ol-14 (XVIII) and 2,2,3,7,11,15-hexamethylheptadecatetraen-3,7,11,16-ol-15 (XX) (see Table 5).

SUMMARY

Analogues of nerolidol, farnesylacetone and geranylinalool were synthesized by successive repetition of the condensation of ketones with acetylene under pressure, selective hydrogenation of the acetylene alcohols thus obtained into vinyl alcohols and conversion of the latter into ketones by heating with acetoacetic ester. The compounds obtained are of interest for the synthesis of the corresponding analogues of phytol, which is a component part of vitamins K and E.

LITERATURE CITED

- [1] I. N. Nazarov et al., Proc. Acad. Sci. USSR, 114, 331, 795, 1029, 1242 (1957).**
[2] I. N. Nazarov, S.M. Makin, V.B. Mochalin, O.A. Shavrygina, D.V. Nazarova, and V.K. Kruptsov, J. Gen. Chem. 29, 544 (1959).**

*The semicarbazones and 2,4-dinitrophenylhydrazones of ketones (XI)-(XIII) were liquids.

**Original Russian pagination. See C.B. Translation.

[3] L. N. Nazarov, B. P. Gusev and V. I. Gunar, *Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1957, 1267.*

[4] L. N. Nazarov et al, *J. Gen. Chem.* 23, 1900 (1953); *Bull. Acad. Sci. USSR, Div. Chem. Sci.* 1956, 960, 1370.*

[5] L. Ruzicka et al, *Helv. Chim. Acta*, 2, 182 (1919); 6, 492 (1923); 22, 392 (1939); F. Fischer and K. Lowenberg, *Lieb. Ann.*, 475, 183 (1929); P. Karrer et al, *Helv. Chim. Acta*, 26, 174 (1943).

[6] G. I. Samokhvalov, M. A. Miropol'skaya and N. A. Preobrazhenski, *Proc. Acad. Sci. USSR*, 107, 103 (1956).*

[7] L. N. Nazarov, V. N. Rakcheeva, V. Ya. Raigorodskaya and L. L. Azerbaev, *Bull. Acad. Sci. USSR, Div. Chem. Sci.* 1946, 305.

[8] M. F. Carrol, *J. Chem. Soc.*, 1940, 704.

Received March 28, 1958

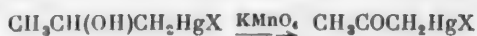
* Original Russian pagination. See C.B. Translation.

PREPARATION OF MONOMERCURATED KETONES FROM ALKENES

I. F. Lutsenko and R. I. Sivkova

Moscow State University

One of the most important and specific reactions for the synthesis of organic derivatives of mercury is the addition of mercury salts to carbon-carbon double bonds. This reaction, which was discovered by Kuchero [1] and then widely studied by Hofmann and Sand [2], makes it easy to obtain mercury derivatives of alcohols containing a mercury atom and the alcohol group at neighboring carbon atoms. Soon after the development of methods of synthesizing mercurated alcohols from alkenes, Sand and Genssler [3] attempted to oxidize the readily available mercurated isopropyl alcohol into monomercurated acetone using potassium permanganate.



After the oxidation and removal of the manganese dioxide, alkali was added to give a completely insoluble compound, $\text{C}_6\text{H}_{12}\text{O}_5\text{Hg}_2$.

Recently developed methods of synthesizing monomercurated aldehydes and ketones [4-8] have made these compounds accessible and made it possible to study their properties. It was found that the addition of very small amounts of alkali to a solution of an organomercury aldehyde or ketone produced an irreversible process forming an amorphous, insoluble product.

This explains why Sand and Genssler were unable to isolate mercurated acetone, the product of the oxidation of mercurated isopropyl alcohol.

We developed a method of preparing monomercurated ketones by a potassium permanganate oxidation in an aqueous acetone medium of the readily available products of adding mercury salts to olefin bonds. The alkali formed in the potassium permanganate oxidation was neutralized by the preliminary addition of a small excess of acetic acid.

Using the method we proposed, starting from propylene, pentene-1, hexene-1, heptene-1, octene-1 and styrene, we prepared the following monomercurated ketones: acetone, methyl propyl ketone, methyl butyl ketone, methyl amyl ketone, methyl hexyl ketone and acetophenone. The yields were 50-60%, calculated on

Monomercurated Ketones, Obtained from Alkenes

Sample No.	Compound	Yield on alkene (in %)	Melting point	Hg content (in %)	
				found	calc.
1	$\text{CH}_3\text{COCH}_2\text{HgCl}$	53	102.5°	68.51	68.43
2	$\text{C}_3\text{H}_7\text{COCH}_2\text{HgCl}$	45	Oil	62.38	62.48
3	$\text{C}_4\text{H}_9\text{COCH}_2\text{HgCl}$	58	62°	59.95	59.85
4	$\text{C}_5\text{H}_{11}\text{COCH}_2\text{HgCl}$	27	75.5	57.52	57.44
5	$\text{C}_6\text{H}_{13}\text{COCH}_2\text{HgCl}$	52	93	55.06	55.22
6	$\text{C}_6\text{H}_5\text{COCH}_2\text{HgOCOC}_2\text{H}_5$	50	109	52.86	52.96

the starting alkenes (see table). The monomercurated alcohols, obtained by addition of mercury salts to the alkenes, were not isolated from the reaction medium. The melting points of the monomercurated ketones obtained were 1-2° lower than those reported in the literature and this is evidently connected with the presence of small traces of unoxidized mercurated alcohol. Chloromercurimethyl propyl ketone was an oil.

EXPERIMENTAL

1. Preparation of chloromercuriacetone from propylene. Propylene was passed through a solution of 16 g of mercuric acetate in 150 ml of water until the reaction for mercury ions disappeared. To the filtered solution was added 6 ml of acetic acid and then 5.3 g of KMnO_4 in small portions with stirring. At the end of the reaction, the solution was heated for 15 minutes on a water bath to precipitate colloidal manganese dioxide. The precipitate was filtered off and washed with warm water. To the filtrate was added a solution of 3.7 g of potassium chloride. The water was removed in vacuum at room temperature. The yield of chloromercuriacetone was 7.75 g (53%) and the m. p. 102-102.5° (from methanol). Literature data [7]; m. p. 103-104°.

2. Preparation of chloromercurimethyl butyl ketone from hexene-1. To a solution of 12.8 g of mercuric acetate in 30 ml of water was added 3.36 g of hexene-1. The oily precipitate of acetatomercurimethylbutylcarbinol was dissolved in a small amount of acetone and 4 ml of acetic acid was added, followed by 4.2 g of KMnO_4 in small portions with stirring. The manganese dioxide was filtered off and washed with hot acetone. To the filtrate was added a solution of 3 g of potassium chloride in 5 ml of water. The precipitated oil crystallized after some time. The yield of chloromercurimethyl butyl ketone was 7.8 g (58%) and the m. p. 61-62° (from a mixture of benzene and octane). Literature data [8]; m. p. 64°.

Chloromercurimethyl amyl ketone and chloromercurimethyl hexyl ketone were synthesized analogously.

3. Preparation of acetatomercuriacetophenone from styrene. To a solution of 8 g of mercuric acetate in 25 ml of water was added 2.5 g of styrene. The oily precipitate of acetatomercurimethylphenylcarbinol was dissolved in a small amount of acetone and acidified with 3 ml of acetic acid. Then 2.7 g of KMnO_4 was added in small portions. At the end of the oxidation, the manganese dioxide was filtered off and washed with acetone. Evaporation of the acetone from the filtrate yielded crystals of acetatomercuriacetophenone. The yield was 4.7 g (50%) and the m. p. 109° (from alcohol and then from benzene).

SUMMARY

A preparative method was developed for obtaining mercurated ketones from alkenes of the type $\text{RCH} = \text{CH}_2$ by permanganate oxidation of the mercurated alcohols obtained from the latter.

LITERATURE CITED

- [1] M. G. Kucherov, J. Rus. Chem. Soc., 24, 330 (1892).
- [2] K. A. Hofmann and J. Sand, Ber. 33, 1340, 1353 (1900).
- [3] J. Sand and O. Genssler, Ber. 36, 3704 (1903).
- [4] A. N. Nesmeyanov, I. F. Lutsenko and N. N. Vereshchagina, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1947, 63.
- [5] A. N. Nesmeyanov, I. F. Lutsenko and Z. M. Tumanova, Bull. Acad. Sci. USSR, Div. Chem. Sci., 1949, 601.
- [6] A. N. Nesmeyanov, I. F. Lutsenko and S. N. Ananchenko, Sci. Rep. Moscow State University, 132, 136 (1950).
- [7] A. N. Nesmeyanov, I. F. Lutsenko and R. M. Khomutov, Proc. Acad. Sci. USSR, 88, 897 (1953).
- [8] I. F. Lutsenko and R. M. Khomutov, Proc. Acad. Sci. USSR, 102, 97 (1955).

Received March 17, 1958

SULFONIC ESTERS OF CYCLOHEXANEDIOLS AND 1,4-BUTANEDIOL

K. V. Levshina, A. K. Chizhov, Yu. N. Sheinker, and

S. I. Sergievskaya

S. Ordzhonikidze All-Union Chemicopharmaceutical Scientific Research Institute

Among the alkylsulfonic esters of aliphatic diols were found substances [1] which are useful in the treatment of certain types of cancerous diseases. For example, dimethanesulfonyl-1,4-butanediol (Myleran and in the USSR, Mielosan) is used in the treatment of chronic myeloid leukemia. While developing an industrial method for the preparation of Mielosan, we did some work on the preparation of its analogs in order to elucidate the effect of the structure of sulfonic esters on their biological properties. It seemed worthwhile to us to publish the material we have on this problem now, since this field of compounds continues to attract the attention of investigators and Myleran occupies a definite position in oncology.

Firstly, we were interested in whether the biological properties of sulfonic esters of 1,4-butanediol were affected by the size and structure of the radical at the sulfur and secondly, whether it was necessary that the diol should belong to the aliphatic series. We synthesized alkylsulfonic esters of 1,4-butanediol with the radicals C_2H_5 , C_3H_7 and $cyclo-C_6H_{11}$ and alkylsulfonic esters of the isomeric cyclohexanediols (1,2; 1,3 and 1,4). All the compounds mentioned were prepared by the reaction of the appropriate sulfonyl chlorides and diols in anhydrous benzene solution in the presence of triethylamine. The sulfonyl chlorides were obtained by the action of chlorine on the alkyl thiocyanates [2]. The exception was cyclohexylsulfonyl chloride, which was obtained by the action of thionyl chloride on cyclohexanesulfonic acid [3].

The synthesis of the sulfonic esters of the cyclohexanediols was complicated by the necessity for preparing the starting cyclohexanediols and for this we used the catalytic hydrogenation of the appropriate dihydric phenols. We also prepared 1,4-cyclohexanediol by a noncatalytic method, starting from succinylsuccinic ester [4].

In the preparation of cyclohexanediols, we used literature data based on the classical stereochemistry of cyclohexane, since practical data of classical stereochemistry on the number of stereoisomers (cis- and trans-) remains correct at the present time. In the preparation of cyclohexanediols and their sulfonic esters and the separation of the stereoisomers, we did not obtain any essentially new data and therefore we report the required information on this part of the work in the experimental part of the article.

We prepared only the methanesulfonic esters of 1,2- and 1,3-cyclohexanediols. The 1,2-cyclohexanediols were not separated into stereoisomers and the methanesulfonic esters were prepared by the action of methanesulfonyl chloride on the mixture of stereoisomers, obtained by the hydrogenation of pyrocatechol. In experiments on the separation of the mixture of stereoisomeric sulfonic esters, it was possible to isolate only the trans compound. The mixture of cis- and trans-1,3-cyclohexanediols was resolved into stereoisomers and the methanesulfonic esters were isolated in both the cis and the trans forms.

We were particularly interested in the alkylsulfonic esters of 1,4-cyclohexanediol, since in structure they are most similar to the esters of 1,4-butanediol, which has the highest activity [1]. Therefore, we prepared not only the methanesulfonates, but also the ethane- and propanesulfonates.

The mixture of stereoisomeric 1,4-cyclohexanediols was resolved into cis and trans isomers by recrystallization. Two series of alkylsulfonates were prepared, starting from the cis- and trans-diols. However, the

supposed *cis* and *trans* forms of the alkylsulfonates had the same melting points and other physicochemical properties. Mixed melting points of the supposed stereoisomers were not depressed. Also, the infrared absorption spectra* of supposed stereoisomeric alkylsulfonates were found to be identical, while the original 1,4-diols and the isomeric alkylsulfonates of 1,2- and 1,3-cyclohexanediols had noticeably different spectra (Figs 1 and 2).

Thus it was established that in the reaction of the corresponding alkylsulfonyl chlorides with *cis*- and *trans*-1,4-cyclohexanediols, only one substance was formed and consequently during the reaction there was inversion of the less stable form into the more stable one.

Starting from the fact that a change in the alkyl group in the 1,4-alkylsulfonates of cyclohexane obtained (methyl-, ethyl- and propylsulfonates) led to an extremely small change in the spectrum, while most of the basic bands were retained (Fig. 3), it can be concluded that the different alkylsulfonates had the same configuration; moreover, according to the usual ideas on the stability of *cis* and *trans* compounds, it can be assumed that we were dealing with the *trans* form in this case.

The biological properties of the compounds we obtained are reported in the appropriate literature. In general they were similar to Myleran; certain of the compounds were less toxic, but also less active than Myleran.

Our work is only of tentative character; however, its development in the section concerned with sulfonic esters of alicyclic compounds is of interest, since in this field of compounds there is the possibility of following the effect of the steric structure of the substances on the growth of malignant cells. We hope that our work will serve as a stimulant for further investigations in this direction.

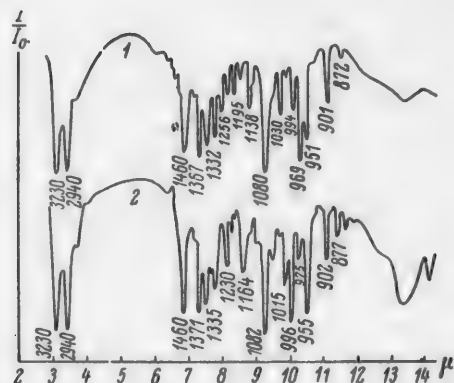


Fig. 1. Infrared absorption spectra. 1) *cis*-1,4-cyclohexanediol, 2) *trans*-1,4-cyclohexanediol.

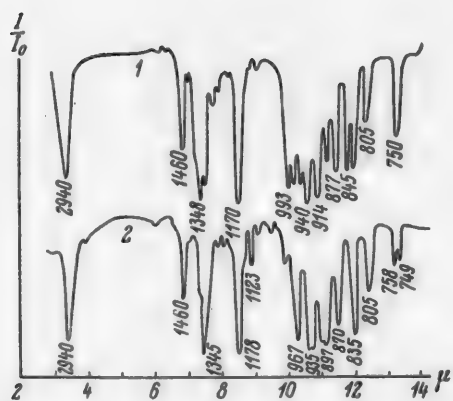


Fig. 2. Infrared absorption spectra. 1) *cis*-dimethylsulfonyl-1,3-cyclohexanediol; 2) *trans*-dimethylsulfonyl-1,3-cyclohexanediol.

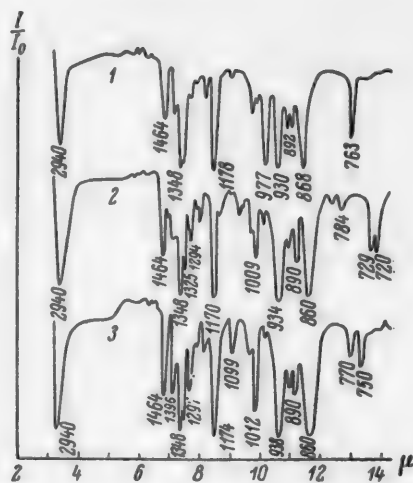


Fig. 3. Infrared absorption spectra. 1) dimethylsulfonyl-1,4-cyclohexanediol; 2) diethylsulfonyl-1,4-cyclohexanediol; 3) dipropylsulfonyl-1,4-cyclohexanediol.

* The infrared absorption spectra were obtained by means of an IKS-11 recording spectrometer (NaCl prism). All the substances were examined in the crystalline form as a paste in vaseline oil.

Dialkylsulfonates Synthesized

Sam- ple No.	Name of compound	Formula	Melting point	% C		% H		% S	
				found	calc.	found	calc.	found	calc.
1	1,4-Di-(propanesulfonyl)-butanediol	$(C_3H_7SO_2O)_2(CH_2)_4$	44—45°	39.79	39.72	7.33	7.28	20.94	21.21
2	1,4-Di-(cyclohexanesulfonyl)-butanediol	$(C_6H_{11}SO_2O)_2(CH_2)_4$	72—74	50.35	50.24	7.68	7.95	—	—
3	1,4-Di-(methanesulfonyl)-cyclohexanediol (from trans-cyclohexanediol)	$1,4-(CH_3SO_2O)_2C_6H_{10}$ (trans)	117—118	35.20	35.30	5.74	5.92	23.65	23.53
4	1,4-Di-(methanesulfonyl)-cyclohexanediol (from cis-cyclohexanediol)	$1,4-(CH_3SO_2O)_2C_6H_{10}$	119—120	—	—	—	—	23.37	23.53
5	1,4-Di-(ethanesulfonyl)-cyclohexanediol (from trans-cyclohexanediol)	$1,4-(C_2H_5SO_2O)_2C_6H_{10}$ (trans)	118—120	40.22	39.98	6.40	6.71	21.51	21.34
6	1,4-Di-(ethanesulfonyl)-cyclohexanediol (from cis-cyclohexanediol)	$1,4-(C_2H_5SO_2O)_2C_6H_{10}$	118—120	40.20	39.98	6.52	6.71	21.30	21.34
7	1,4-Di-(propanesulfonyl)-cyclohexanediol (from trans-cyclohexanediol)	$1,4-(C_3H_7SO_2O)_2C_6H_{10}$ (trans)	98—101	43.78	43.88	7.09	7.36	19.69	19.52
8	1,4-Di-(propanesulfonyl)-cyclohexanediol (from cis-cyclohexanediol)	$1,4-(C_3H_7SO_2O)_2C_6H_{10}$	98—101	43.90	43.88	7.53	7.36	—	—
9	1,3-Di-(methanesulfonyl)-cyclohexanediol (from trans-cyclohexanediol)	$1,3-(CH_3SO_2O)_2C_6H_{10}$ (trans)	94—96	35.59	35.30	5.71	5.92	24.26	23.53
10	1,3-Di-(methanesulfonyl)-cyclohexanediol (from cis-1,3-cyclohexanediol)	$1,3-(CH_3SO_2O)_2C_6H_{10}$ (cis)	123—124	35.76	35.30	5.91	5.92	24.01	23.53
11	1,2-Di-(methanesulfonyl)-cyclohexanediol (from trans-1,2-cyclohexanediol)	$1,2-(CH_3SO_2O)_2C_6H_{10}$ (trans)	133.7—134.5	35.19	35.30	6.22	5.92	23.83	23.53

EXPERIMENTAL

Di(ethanesulfonyl)-1,4-butanediol. To a mixture of 2.08 g of 1,4-butanediol, 4.68 g of triethylamine and 20 ml of anhydrous benzene, cooled to 6-7°, was gradually added 6 g of ethanesulfonyl chloride, while the temperature was not allowed to rise above 15°. The precipitated triethylamine hydrochloride was removed by filtration and the benzene filtrate gradually deposited a colorless, crystalline substance, which was insoluble in water and melted at 38-39.5° after recrystallization from alcohol.

Found %: S 23.7. $C_8H_{18}O_6S_2$. Calculated %: S 23.4.

Di(propanesulfonyl)-1,4-butanediol, di(cyclohexanesulfonyl)-1,4-butanediol and dialkylsulfonylcyclohexanediols were prepared in the same way (see Table).

1,2-Cyclohexanediol and trans-1,2-dimethanesulfonylcyclohexanediol. We used 50 g of pyrocatechol, 40 ml of 94% alcohol and 10 g of Raney nickel. The hydrogenation* was performed in an autoclave; the initial hydrogen pressure was 98 atm at 20°, absorption of hydrogen occurred at 140° and the maximum hydrogen pressure was 126 atm. We obtained 52 g of a mixture of cis- and trans-1,2-cyclohexanediols with m. p. 73°. The action of methanesulfonyl chloride on the mixture of cis- and trans-1,2-cyclohexanediols and subsequent recrystallization of the material obtained from water yielded a substance with m. p. 133.7-134.5°. According to literature data, this melting point corresponds to that of trans-1,2-dimethanesulfonylcyclohexanediol.

Cis- and trans-1,3-cyclohexanediols and their dimethanesulfonic esters. A mixture of cis- and trans-1,3-cyclohexanediols was obtained by the hydrogenation of resorcinol in the presence of Raney nickel according to the data in [6]. The b. p. was 135-137° (13 mm), n_D^{20} 1.4922-1.4940. The mixture was resolved into stereoisomers by conversion of the 1,3-cyclohexanediols into their dibenzoates and separation of the latter into cis and trans isomers by recrystallization [7]. The cis-dibenzoate (m. p. 64-65°) and the trans-dibenzoate (m. p. 124.7-125.2°) were obtained. Hydrolysis of the dibenzoates yielded cis- and trans-1,3-cyclohexanediols. The cis compound was obtained in a very small amount.

Di(methanesulfonyl)-1,3-cyclohexanediols. To 5.07 g of a mixture of cis- and trans-1,3-cyclohexanediols and 8.83 g of triethylamine, dissolved in anhydrous benzene, was added 10 g of methanesulfonyl chloride. The reaction proceeded at 10-20°. On standing for a day, the solution deposited a crystalline precipitate of the cis-dimethylsulfonate; after recrystallization from aqueous alcohol, the substance had m. p. 123.6-124°. The benzene was distilled in vacuum from the benzene solution remaining after separation of the cis isomer; the residue was recrystallized many times from methanol and had m. p. 86-87.5°. A sample for analysis and physical investigations was further recrystallized to give a substance with m. p. 90-91°. Trans-dimethylsulfonyl-1,3-cyclohexanediol was also prepared by the action of methanesulfonyl chloride on trans-1,3-cyclohexanediol, obtained by hydrolysis of the trans-dibenzoate. The trans-dimethanesulfonate had m. p. 94-96°.

1,4-Cyclohexanediols and their dialkylsulfonic esters. A mixture of cis- and trans-1,4-cyclohexanediols was obtained by hydrogenation of hydroquinone in the presence of Raney nickel [8] at a hydrogen pressure of 100 atm and 120-130°. The substance obtained was resolved into cis and trans isomers by recrystallization from acetone, which yielded 1 part of trans isomer to 3 parts of cis isomer. The dialkylsulfonates of the cis and trans isomers were obtained by the method described above for the preparation of the diethanesulfonic ester of 1,4-butanediol. The constants and analyses are given in the Table.

SUMMARY

1. Alkylsulfonic esters of 1,4-butanediol and isomeric cyclohexanediol were prepared
2. The alkylsulfonic esters obtained from cis- and trans-1,4-cyclohexanediols had the same melting points and infrared absorption spectra and on the basis of this it can be assumed that during the formation of the alkylsulfonic esters, inversion of the less stable steric form into the more stable one occurred.

* We did not use the methods of hydrogenating pyrocatechol reported in the literature [5] and the hydrogenation was accomplished by a method similar to the one described for the hydrogenation of resorcinol [6].

LITERATURE CITED

- [1] G. Timmis and A. Haddow, *Lancet*, 1, 207 (1953); *Pharm. J.*, 168, 383 (1952).
- [2] A. G. Kostsova, *J. Gen. Chem.* 18, 730 (1948).
- [3] W. Borsche and W. Lange, *Ber.* 38, 2766 (1905).
- [4] A. E. Uspenskiĭ, *J. Russ. Chem. Soc.* 52, 263 (1920).
- [5] German Pat. 857,962; *Ch. A.* 44, 3445e (1950); *Ch. A.* 47, 11239e (1950).
- [6] K. Dimroth and K. Resin, *Ber.* 75, 322 (1942).
- [7] M. F. Clarke and L. N. Owen, *J. Chem. Soc.*, 1949, 315; 1950, 2103.
- [8] *Ch. A.* 46, 5538f (1952).

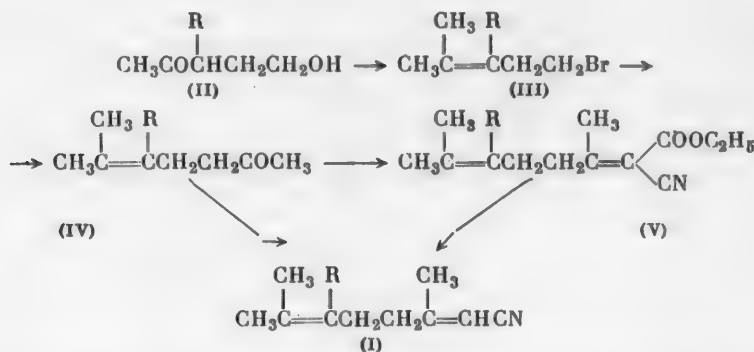
Received February 10, 1958

SYNTHESIS OF 7-CYANO-2,6-DIMETHYL- AND 2,3,6-TRIMETHYL-HEPTADIENES-2,6, THE NITRILES OF GERANIC AND 3-METHYLGERANIC ACIDS

I. K. Sarycheva, E. M. Shustorovich, G. A. Vorob'eva, and
N. A. Preobrazhenskii
Moscow Institute of Fine Chemical Technology

The synthesis of nitrogen-containing compounds of the terpene series is of considerable interest since these substances, for example, amines and nitriles, provide an approach to the preparation of geraniol, citral, geranic acid and their many homologs [1].

In this article, a synthesis is described for the nitriles of geranic (I, R = H) and 3-methylgeranic (I, R = CH₃) acids from 2-methylhepten-2-one-6 (IV, R = H) and 2,3-dimethylhepten-2-one-6 (IV, R = CH₃), respectively.



The starting 2-methylhepten-2-one-6 (IV, R = H) was synthesized from γ -acetopropyl alcohol (II, R = H), which was converted into 5-bromo-2-methylpentene-2 (III, R = H) by the procedure we proposed previously [2]. The bromide obtained was then condensed with acetic anhydride in the presence of magnesium [3]. In order to synthesize the nitrile of geranic acid (I, R = H), 2-methylhepten-2-one-6 (IV, R = H) was reacted with cyanoacetic acid. Compound (I, R = H) was also obtained by the reaction of 2-methylhepten-2-one-6 (IV, R = H) with ethyl cyanoacetate and subsequent selective hydrolysis and decarboxylation of the ethyl ester of 7-cyano-2,6-dimethyloctadien-2,6-oic-(8) acid (V, R = H). The nitrile of 3-methylgeranic acid (I, R = CH₃) was synthesized similarly, using 2,3-dimethylhepten-2-one-6 [4] (IV, R = CH₃) and ethyl cyanoacetate. For confirmation of the structure, the nitrile of geranic acid (I, R = H) synthesized was reduced with lithium aluminum hydride to geranylamine (VI) and then converted to a mixture of geraniol (VII) and nerol (VIII) by the action of nitrous acid [5].

The observed discrepancy between the physicochemical constants of the nitrile of geranic acid (I, R = H), obtained by the synthetic method (b. p. 78-78.5° at 2 mm and n_D^{20} 1.4718) and those of the material prepared

$$\begin{array}{c}
 \text{CH}_3 \qquad \qquad \text{CH}_3 \\
 | \qquad \qquad \quad | \\
 \text{(I, R=H)} \rightarrow \text{CH}_3\text{C}=\text{CHCH}_2\text{CH}_2\text{C}=\text{CHCH}_2\text{NH}_2 \\
 \text{(VI)}
 \end{array}
 \begin{array}{l}
 \nearrow \begin{array}{c} \text{CH-CH}_2\text{OH} \\ | \\ \text{(VII)} \end{array} \\
 \searrow \begin{array}{c} \text{H}_2\text{CCH} \\ | \quad || \\ \text{HO} \end{array} \\
 \text{(VIII)}
 \end{array}$$

$$\begin{array}{c}
 \text{CH}_3 \qquad \qquad \text{CH}_3 \qquad \qquad \text{CH}_3 \qquad \qquad \text{CH}_3 \\
 | \qquad \qquad \quad | \qquad \qquad \quad | \qquad \qquad \quad | \\
 \text{CH}_3\text{C}=\text{CHCH}_2\text{CH}_2\text{C}=\text{CH}-\text{CHO} \rightarrow \text{CH}_3\text{C}=\text{CHCH}_2\text{CH}_2\text{C}=\text{CHCH}=\text{NOH} \rightarrow \\
 \text{(IX)} \\
 \rightarrow \text{(I, R=H)}
 \end{array}$$

1. 2-Methylhepten-2-one-6 (IV, R = H). Over a period of 25 minutes, the Grignard reagent prepared from 17 g of magnesium and 117.4 g of 5-bromo-2-methylpentene-2 (III, R = H) (b. p. 84-85° at 85 mm) in 150 ml of ether was added to a solution of 143 g of acetic anhydride in 200 ml of absolute ether, cooled to -70°. The mixture was stirred for 2.5 hours at -65 to -70° and then the temperature was raised to 18-19°. The reaction mixture was then decomposed with 210 ml of a saturated aqueous solution of ammonium chloride, neutralized with a 10% aqueous solution of sodium hydroxide and the substance extracted with 250 ml of ether. The combined ether extracts were dried with sodium sulfate. The residue after evaporation of the solvent was distilled. The yield was 46.2 g (50.86%).

2. Ethyl ester of 7-cyano-2,6-dimethyloctadien-2,6-oic-(8) acid (V, R = H). To a solution of 22.5 g of 2-methylhepten-2-one-6 (IV, R = H) and 25.5 g of cyanoacetic ester in 60 ml of anhydrous benzene was added 2.5 ml of piperidine. The mixture was boiled for 3 hours in an atmosphere of nitrogen with continuous distillation of the water formed during the reaction (azeotropic method with benzene). The reaction mixture was then cooled to 0°, washed with 25 ml of hydrochloric acid (d_{40}^{20} 1.047) and 20 ml of water, neutralized with a saturated aqueous solution of sodium bicarbonate and dried with sodium sulfate. The residue after evaporation of the solvent was distilled. The yield was 23.78 g (60.3%).

Found %: C 70.50; H 8.67; N 6.43. $C_{11}H_{19}O_2N$. Calculated %: C 70.53; H 8.65; N 6.33.

B. p. 78-78.5° (2 mm), d_4^{20} 0.8737, n_D^{20} 1.4718, MR_D 47.80; calc. 37.26.

1160

b) A mixture of 21.5 g of 2-methylhepten-2-one-6 (IV, R = H) in 30.6 g of cyanoacetic acid, 75 ml of dry benzene and 3 ml of piperidine was boiled for 3 hours in a stream of dry nitrogen. Simultaneously, the water formed during the reaction was removed with a water separator. Then 1 g of powdered copper was added and heating continued for a further 2.5 hours. The reaction mixture was cooled to 0° and successively treated with 25 ml of hydrochloric acid (d_4^{20} 1.047) and 30 ml of water, neutralized with a saturated aqueous solution of sodium bicarbonate and dried with sodium sulfate. The residue, after removal of the solvent, was distilled. The yield was 14.9 g (58.6%).

B. p. 78-79° (2 mm), d_4^{20} 0.8740, n_D^{20} 1.4719, MR_D 47.79; calc. 47.26.

Found %: N 9.45. $C_{10}H_{15}N$. Calculated %: N 9.39.

4. 8-Amino-2,6-dimethyloctadiene-2,6 (geranylamine VI). Over a period of 20 minutes, 21 g of 7-cyano-2,6-dimethylheptadiene-2,6 (I, R = H) in 75 ml of ether was added to a solution of 5.39 g of lithium aluminum hydride in 260 ml of ether at 19°. The reaction mixture was stirred for 30 minutes and then 20 ml of ice water added. The precipitate was filtered off and washed with 50 ml of ether. The upper layer of the filtrate was separated and the substance extracted from the lower layer with 100 ml of ether. The combined extracts were dried with sodium sulfate. The residue after evaporation of the solvent was distilled. The yield was 7.9 g (36.7%).

B. p. 95-96° (10 mm), d_4^{17} 0.8628, n_D^{17} 1.4780, MR_D 50.26; calc. 50.87.

Found %: C 78.42, 78.13; H 12.26, 12.30; N 9.34, 9.02. $C_{10}H_{19}N$. Calculated %: C 78.38; H 12.49; N 9.12.

5. 2,6-Dimethyloctadien-2,6-ol-8 (VII and VIII). Over a period of 20 minutes a solution of 5 g of sodium nitrite in 22 ml of water was added to a solution of 7.4 g of 8-amino-2,6-dimethyloctadiene-2,6 (VI) in 20 ml of hydrochloric acid (d_4^{20} 1.047), cooled to 0°. The reaction mixture was kept at 20° for 10 minutes, hydrochloric acid (d_4^{20} 1.047) added until the pH was 2 and the mixture heated at 100° for 1 hour. The mixture was again acidified to pH 2 and the reaction product extracted with 100 ml of ether. The residue after evaporation of the solvent was boiled for 1 hour in the presence of 1.2 g of potassium hydroxide in 20 ml of ethyl alcohol, cooled to 15°, treated with 75 ml of ice water and the substance extracted with 75 ml of ether. The combined extracts were dried with sodium sulfate. After removal of the solvent, the compound obtained was distilled. The yield was 3.24 g (43.5%).

B. p. 119-121° (18 mm), d_4^{20} 0.8728, n_D^{20} 1.4708, MR_D 49.35; calc. 48.97.

Found %: C 77.90, 77.85; H 11.66, 11.70. $C_{10}H_{18}O$. Calculated %: C 77.87; H 11.76.

6. Ethyl ester of 7-cyano-2,3,6-trimethyloctadien-2,6-oic-(8) acid (V, R = CH_3). The ester was synthesized under the same conditions as the ethyl ester of 7-cyano-2,6-dimethyloctadien-2,6-oic-(8) acid from 40 g of 2,3-dimethylhepten-2-one-6 (IV, R = CH_3) and 45.4 g of cyanoacetic ester in 130 ml of dry benzene in the presence of 6 ml of piperidine. The yield was 33.6 g (50.1%).

B. p. 108-109.5° (1 mm), 116-117° (1.5 mm), d_4^{20} 0.9970, n_D^{20} 1.4792, MR_D 66.95; calc. 67.39.

Found %: C 71.17, 71.29; H 9.05, 8.98. $C_{14}H_{22}O_2N$. Calculated %: C 71.46; H 9.00.

7. 7-Cyano-2,3,6-trimethyloctadiene-2,6 (nitrile of 3-methylgeranic acid) (I, R = CH_3). 33.2 g of the ethyl ester of 7-cyano-2,3,6-trimethyloctadien-2,6-oic-(8) acid (V, R = CH_3) was hydrolyzed with 5.6 g of sodium hydroxide in 90 ml of anhydrous ethyl alcohol. The reaction mixture was worked up as in experiment 3 for the preparation of 7-cyano-2,6-dimethylheptadiene-2,6 (I, R = H). The yield was 10.1 g (44.1%).

B. p. 120-122° (17 mm), d_4^{20} 0.884, n_D^{20} 1.4718, MR_D 51.82. $C_{11}H_{17}N$. Calculated 51.88.

SUMMARY

1. 7-Cyano-2,6-dimethyl- and 2,3,6-trimethylheptadienes-2,6, the nitriles of geranic and 3-methylgeranic acids, were synthesized.

2. During the course of the synthesis, the ethyl esters of 7-cyano-2,6-dimethyloctadien-2,6-oic-(8) and 7-cyano-2,3,6-trimethyloctadien-2,6-oic-(8) acids were isolated and characterized.

LITERATURE CITED

- [1] H. Plieninger and G. Werst, *Angew. Ch.*, 67, 156 (1955); N. S. Drozdov and A.F. Bekhli, *J. Gen. Chem.* 14, 280 (1944); H. Steppen, *J. Chem. Soc.* 127, 1874 (1925).
- [2] L. K. Sarycheva, N. A. Preobrazhenskii, et al., *J. Gen. Chem.*, 25, 2001 (1955).*
- [3] S. M. Newman and W. T. Booth, *J. Am. Chem. Soc.* 67, 154 (1945).
- [4] I. K. Sarycheva, G. A. Vorob'eva, L. G. Kucheryavenko and N. A. Preobrazhenskii, *J. Gen. Chem.* 27, 2994 (1957).*
- [5] G. I. Samokhvalov, M. A. Miropol'skaya and N. A. Preobrazhenskii, *J. Gen. Chem.*, 26, 54, 2793 (1956).*
- [6] F. Tiemann, *Ber.*, 26, 2717 (1893).
- [7] Takamidzava, *J. Pharm. Soc. Japan*, 74, 748 (1954).

Received March 31, 1958

* Original Russian pagination. See C.B. Translation.

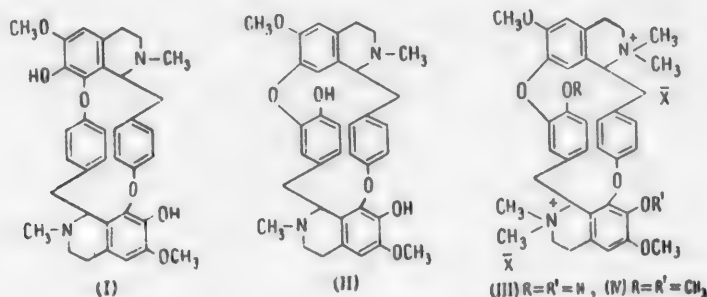
SYNTHESIS OF THE DIMETHYL ETHER OF THE ALKALOID

(±)-TUBOCURARINE IODIDE

O. N. Tolkachev, V. G. Voronin and N. A. Preobrazhenskii

Moscow Institute of Fine Chemical Technology

An extract of the plants *Chondrodendron tomentosum* and certain forms of *Strychnos*, known under the name of curare, is used by South American Indians as an arrow poison [1]. Resolution of the mixture of curare alkaloids yielded compounds of two forms: 1) tertiary bases without specific curare activity, but acting as general depressant poisons; to this group belong isochondrodendrine (I), chondrodendrine (II) and certain others; 2) quaternary ammonium salts, curarines, which cause the high and specific physiological activity of curare; amongst the compounds of this type, there is the greatest practical interest in (±)-tubocurarine chloride and tubocurarine (III).



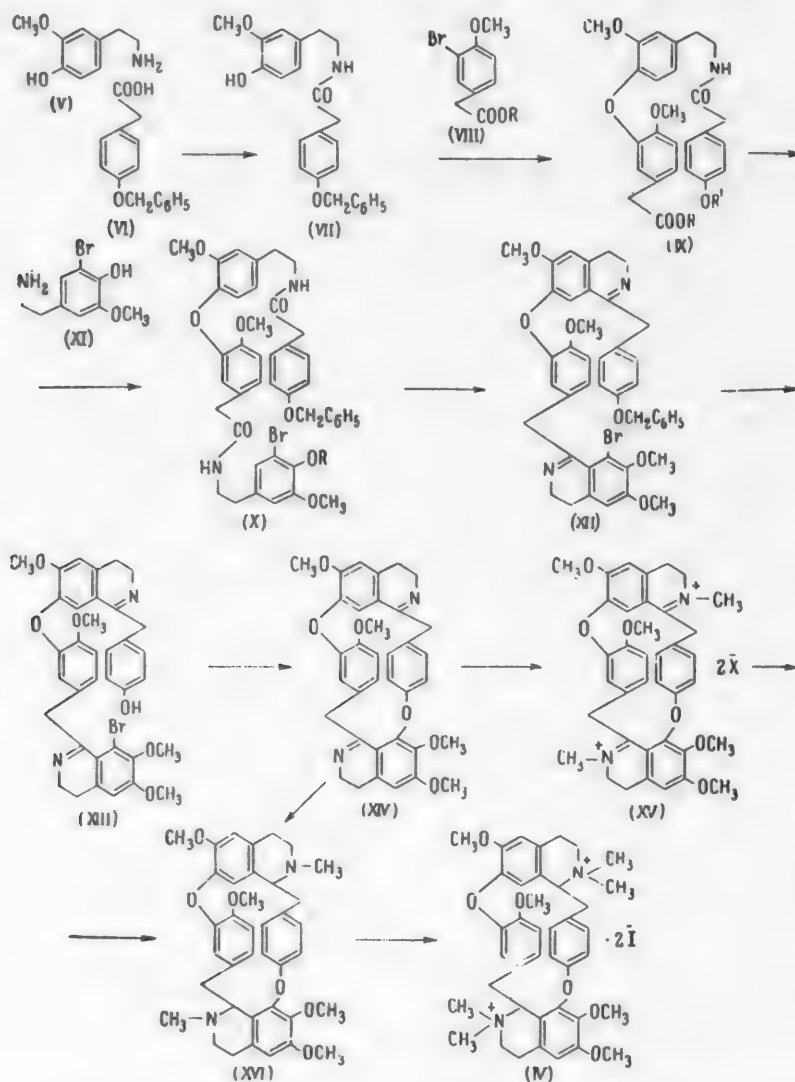
The physiological action of tubocurarine appears as complete prostration of the transversostriated muscles, which causes the paralysis of animals ("curare paralysis") [2]. The O,O-dimethyl derivative of tubocurarine (IV), which is 2-10 times more active, is used in medicine in complex abdominal operations [3].

Despite the fact that the physiological activity of curare has been known since the sixteenth century, the alkaloid (±)-tubocurarine chloride was isolated for the first time in a pure crystalline form only in 1935 [4]. In addition, up to now the chemical structure of tubocurarine remains unconfirmed synthetically, although intensive work is being carried out in this direction [5].

Our investigations were directed towards a scheme for preparing dimethyl ethers of open curarines and the dimethyl ether of (±)-tubocurarine was synthesized for the first time [6]. In the present report is described the synthetic preparation of the dimethyl ether of (±)-tubocurarine iodide by a scheme which opens up a route to the synthesis of the isomeric tertiary bases, curines, and the salts of the quaternary bases, curarines. The basis of the scheme is the successive build-up of a system, having the elements of the natural alkaloid, and the final stage is the formation of the second oxygen bridge.

β-(3-Methoxy-4-hydroxyphenyl)-ethylamine (V), obtained by catalytic reduction of the appropriate ω-nitrostyrene [7] was condensed with 4-benzyloxyphenylacetic acid (VI) at 190-200° to give the β-(3-methoxy-4-hydroxyphenyl)-ethylamide of 4'-benzyloxyphenylacetic acid (VII). Reaction of the potassium salt of the latter with (methyl or ethyl) esters of 3-bromo-4-methoxyphenylacetic acid (VIII, R = CH₃ or C₂H₅) in the

presence of copper powder at 190-200° gave the β -[3-methoxy-4-(2"-methoxy-5"-carbalkoxymethylphenoxy)-phenyl]-ethylamide of 4'-benzyloxyphenylacetic acid (IX, R = CH₃ or C₂H₅; R' = CH₂C₆H₅).



The substances obtained were hydrolyzed with an aqueous alcohol solution of potassium carbonate or sodium carbonate into the corresponding acid (IX, R = H, R' = CH₂C₆H₅), and debenzylated with palladium into the β -[3-methoxy-4-(2"-methoxy-5"-carboxymethylphenoxy)-phenyl]-ethylamide of 4'-hydroxyphenylacetic acid (IX, R = R' = H). The β -3-Methoxy-4-[2"-methoxy-5"--(β "'-3"-methoxy-4"-hydroxy-5"-bromophenyl)-ethylcarbamidomethyl]-phenoxy]-phenyl-ethylamide of 4'-benzyloxyphenylacetic acid (X, R = H) was obtained from (IX, R = CH₃ or C₂H₅, R' = CH₂C₆H₅) and β -(3-methoxy-4-hydroxy-5-bromophenyl)-ethylamine (XI) at 180° and from (IX, R = H, R' = CH₂C₆H₅) and (XI) at 190°. The compound (X, R = H) was methylated with methyl iodide to give the β -3-methoxy-4-[2"-methoxy-5"--(β "'-3"-methoxy-4"-dimethoxy-5"-bromophenyl)-ethylcarbamidomethyl]-phenoxy]-phenyl-ethylamide of 4'-benzyloxyphenylacetic acid (X, R = CH₃), which was then cyclized with phosphorus oxychloride in chloroform solution. This formed a mixture of a phosphate and hydrochloride, from which we isolated the free base, 1-(4'-benzyloxybenzyl)-6-methoxy-7-[2"-methoxy-5"--(6"-',7"-dimethoxy-8"-bromo-3"-',4"-dihydroisquinolyl)-1"-methyl]-phenoxy]-3,4-dihydroisquinoline (XII). The benzyloxy group of the latter was hydrolyzed with 20% hydrochloric acid and finally the 1-(4'-hydroxybenzyl)-6-methoxy-7-[2"-methoxy-5"--(6"-',7"-dimethoxy-8"-bromo-3"-',4"-

dihydroisoquinolyl-1'' '-methyl)-phenoxy]-3,4-dihydroisoquinoline (XIII) obtained was heated in the presence of copper, potassium carbonate and pyridine to give 1,2,1'' ',2'' '-tetrahydro-O-methylchondrofolin (XIV). After reduction with zinc dust in acetic acid, the latter was methylated to yield O,O'-dimethylchondodendrine (XVI), which was also obtained from the dimethiodide of 1,2,1'' ',2'' '-tetrahydro-O-methylchondrofoline (XV, X = I). Then, by the action of methyl iodide, (XVI) was converted into the dimethyl ether of (±)-tubocurarine iodide (IV), whose ultraviolet spectrum was found to be identical with the spectrum of the corresponding dimethyl ether of natural (+)-tubocurarine iodide. A mixed melting point of these substances was not depressed.

EXPERIMENTAL

1. β -(3-Methoxy-4-hydroxyphenyl)-ethylamide of 4'-benzyloxyphenylacetic acid (VII). 83 g of 3-methoxy-4-hydroxyphenylethylamine and 120 g of 4-benzyloxyphenylacetic acid were heated with stirring in a stream of nitrogen for 1 hour at 190-200°. The cooled reaction mixture was ground with ether (20 times with 45-50 ml portions). The yield was 96.5%. The m. p. was 120-121° (from ethyl alcohol).

Found %: N 3.55, 3.49. $C_{24}H_{25}O_4N$. Calculated %: N 3.58.

2. β -[3-Methoxy-4-(2''-methoxy-5''-carbalkoxymethylphenoxy)-phenyl]-ethylamide of 4'-benzyloxyphenylacetic acid (IX). a) IX, R = C_2H_5 , R' = $CH_2C_6H_5$. To a solution of 2.1 g of potassium in 60 ml of anhydrous alcohol was added 17.5 g of the β -(3-methoxy-4-hydroxyphenyl)-ethylamide of 4'-benzyloxyphenylacetic acid and then the alcohol was removed in vacuum. The residue was ground up well and to it was added 22.8 g of the ethyl ester of 3-bromo-4-methoxyphenylacetic acid (b. p. 142-144° at 3 mm) and 8 g of copper powder. After being heated for 1 hour at 190-195° in a stream of nitrogen, the reaction mass was ground with ether (10 times with 80 ml portions) and the residue dissolved in 300 ml of acetone or chloroform and filtered free from copper and potassium bromide. Removal of the solvent in vacuum yielded a light-brown substance. The yield was 19.5 g (74.8%). The m. p. was 94-96°.

b) IX, R = CH_3 , R' = $CH_2C_6H_5$. The yield was 83.8%. The m. p. was 100-101°.

Found %: C 71.10; H 6.55; N 2.64, 2.34. $C_{34}H_{35}O_7N$. Calculated %: C 71.80; H 6.15; N 2.46.

3. β -[3-Methoxy-4-(2''-methoxy-5''-carboxymethylphenoxy)-phenyl]-ethylamide of 4'-benzyloxymethylphenylacetic acid (IX, R = H, R' = $CH_2C_6H_5$). A mixture of 15 g of the β -[3-methoxy-4-(2''-methoxy-5''-carbalkoxymethylphenoxy)-phenyl]-ethylamide of 4'-benzyloxyphenylacetic acid, 5 g of sodium carbonate in 10 ml of water and 120 ml of methyl alcohol were boiled for 2 hours. The alcohol was removed in vacuum and the residue dissolved in 200 ml of water, filtered and acidified with dilute (1:1) hydrochloric acid. The yellow crystalline substance precipitated was collected, washed with water and dried in a desiccator. The yield was 11.4 g (79.8%). The m. p. was 107-108° (from aqueous dimethylformamide, 1:1).

Found %: N 2.54, 2.66. $C_{33}H_{33}O_7N$. Calculated %: N 2.52.

4. β -[3-Methoxy-4-(2''-methoxy-5''-carboxymethylphenoxy)-phenyl]-ethylamide of 4'-hydroxyphenylacetic acid (IX, R = R' = H). A solution of 0.25 g of (IX, R = CH_3 , R' = $CH_2C_6H_5$) in 60 ml of methyl alcohol was hydrogenated in the presence of 0.3 g of palladium black for 3.5 hours. The catalyst was filtered off and the residue obtained after removal of the solvent (0.21 g) boiled for 2 hours with 1 g of potassium carbonate in 3 ml of ether and 7 ml of methyl alcohol. The alcohol was removed in vacuum, 20 ml of water added, the mixture filtered and acidified with 3 ml of dilute (1:1) hydrochloric acid and the precipitate substance separated. The m. p. was 98-100° (from carbon tetrachloride).

Found %: N 2.98, 2.89. $C_{26}H_{27}O_7N$. Calculated %: N 3.02.

5. β -(3-Methoxy-4-[2''-methoxy-5''-(β ' '-(3'' '-methoxy-4'' '-hydroxy-5'' '-bromophenyl)-(ethylcarbamidomethyl)-phenoxy]-phenyl)-ethylamide of 4'-benzyloxyphenylacetic acid (X, R = H). a) A mixture of 20 g of (IX, R = H, R' = $CH_2C_6H_5$) and 9.25 g of β -(3-methoxy-4-hydroxy-5-bromophenyl)-ethylamine (XI) was heated with stirring in a stream of nitrogen at 185-190° for 1 hour. The cooled reaction mixture was dissolved in 450 ml of 2.5% sodium hydroxide, filtered free from impurities and acidified with dilute (1:1) hydrochloric acid. The precipitated diamide was separated, washed with an aqueous solution (1:1) of ammonia and with water and dried. The light-grey substance was soluble in alcohol and acetone and insoluble in benzene and ether. The yield was 27.50 g (99.5%). The m. p. was 99-101°.

Found %: C 64.20, 64.43; H 5.40, 5.23; N 3.67, 3.71. $C_{42}H_{43}O_8N_2Br$. Calculated %: C 64.40; H 5.49; N 3.58.

b) A mixture of 4.87 g of (IX, R = CH₃, R' = CH₂C₆H₅), 2.1 g of (XI) and 20 drops of pyridine was heated in a stream of nitrogen for 2.5 hours at 180-190°. Further processing was as in the previous experiment. The yield was 5.73 g (85.4%). The m. p. was 98-100°.

Found %: C 64.24, 64.16; H 5.16, 6.30; N 3.55, 3.41. $C_{42}H_{43}O_8N_2$. Calculated %: C 64.40; H 5.49; N 3.58.

6. β -(3-Methoxy-4-[2"-methoxy-5"-(β "-(3",4"-dimethoxy-5"-bromophenyl)-ethylcarbamido-methyl)-phenyl]-ethylamide of 4"-benzyloxyphenylacetic acid (X, R = CH₃). To a solution of 50 g of (X, R = H) in 50 ml of methyl alcohol was added 11 g of potassium hydroxide in 100 ml of methyl alcohol and 100 ml of methyl iodide. The mixture was boiled for 5 hours, the solvent removed in vacuum and the residue treated with 400 ml of 2.5% sodium hydroxide and then with chloroform (5 times with 200 ml portions). Drying and removal of the chloroform yielded a light-brown substance, which was soluble in alcohol, acetone, ethyl acetate, chloroform and hot carbon tetrachloride and difficultly soluble in ether. The yield was 48.2 g (95.0%). The m. p. was 79-81°.

Found %: N 3.39; 3.33. $C_{43}H_{45}O_8N_2Br$. Calculated %: N 3.51.

7. 1-(4"-Benzyloxybenzyl)-6-methoxy-7-[2"-methoxy-5"-(6",7"-dimethoxy-8"-bromo-3",4"-dihydroisoquinolyl-1"-methyl)-phenoxy]-3,4-dihydroisoquinoline (XII). A solution of 55 g of (X, R = CH₃) in 300 ml of dry chloroform and 70 ml of phosphorus oxychloride was boiled for 3 hours in a stream of hydrogen. Then 500 ml of dry ether was added to the reaction mass and the precipitate carefully ground with the addition of fresh portions of ether (5 times with 250 ml portions) and decantation. The residue was treated with boiling water (twice with 550 ml portions), filtered and cooled and the solution obtained neutralized with an aqueous solution of ammonia. The substance was colorless and crystalline. The yield was 11 g (20.9%). The m. p. was 119-121°.

The methiodide had m. p. 146-149° (deformed at 129°).

Found %: C 52.10; H 4.21; N 2.36. $C_{45}H_{47}O_6N_2I_2Br$. Calculated %: C 51.70; H 4.50; N 2.68.

8. 1-(4-Hydroxybenzyl)-6-methoxy-7-[2"-methoxy-5"-(6",7"-dimethoxy-8"-bromo-3",4"-dihydroisoquinolyl-1"-methyl)-phenoxy]-3,4-dihydroisoquinoline (XIII). A mixture of 11 g of (XIII) and 150 ml of 20% hydrochloric acid was boiled for 2 hours, then 200 ml of water added and the reaction mixture filtered and neutralized with an aqueous solution of ammonia. The light-yellow substance precipitated was collected and dried. The yield was 9.3 g (94.6%). The m. p. was 150-152°.

Found %: C 64.63, 64.46; H 5.14, 5.20; N 4.33, 4.34. $C_{36}H_{35}O_6N_2Br$. Calculated %: C 64.40; H 5.22; N 4.18.

The dimethiodide had m. p. 182-183° (from alcohol).

Found %: C 47.20; H 5.20; N 2.73, 2.73. $C_{38}H_{41}O_6N_2I_2Br$. Calculated %: C 47.7; H 4.29; N 2.93.

9. 1,2,1", 2"-Tetradehydro-O-methylchondrofoline (XIV). A mixture of 0.42 g of (XIII), 0.22 g of potassium carbonate, 0.40 g of copper powder and 1.5 ml of pyridine was heated in a stream of nitrogen for 60 minutes at 160° and 20 minutes at 180°. The cooled reaction mixture was treated with water (4 times with 20 ml portions) until the filtrate no longer had a green color and the residue extracted with chloroform (5 times with 10 ml portions), filtered, dried with sodium sulfate and the solvent removed in vacuum. For purification, the compound obtained was dissolved in acetone and the solution filtered and concentrated to give a brown substance, which was insoluble in alkalis. The yield was 0.34 g (91%). The m. p. was 96-101°.

Dimethiodide (XV, X = I). The yield was 66.3%. The m. p. was 110-115° (from ethyl alcohol).

Found %: C 52.50; H 5.30; N 3.35, 3.28. $C_{38}H_{40}O_6N_2I_2$. Calculated %: C 52.10; H 4.58; N 3.20.

10. O,O'-Dimethylchondodendrine (XVI). A mixture of 0.61 g of 1,2,1", 2"-tetradehydro-O-methyl-

chondrofoline (XIV), 15 ml of dilute acetic acid (1:1) and 2.5 g of zinc dust was boiled for 1.5 hours. The excess zinc was separated, the filtrate treated with a 10% solution of sodium hydroxide (50 ml) and the substance extracted with chloroform, which, after being washed with water (twice with 10 ml portions), was removed in vacuum. The residue (0.1 g) was boiled for 3 hours with 5 ml of methyl alcohol and 2 ml of methyl iodide. The solvent was removed in vacuum and the residue treated with 45 ml of hot water, filtered, neutralized with an aqueous solution of ammonia and extracted first with ether and then the chloroform. Removal of the latter in vacuum yielded the base, O,O'-dimethylchondodendrine. The yield was 0.075 g (11.7%).

The dihydroiodide had m. p. 181-185° (from alcohol).

The same substance was formed by reduction of the dimethiodide of 1,2,1'',-2''-tetrahydro-O-methylchondrofoline (XV, X = I) with zinc in acetic acid.

11. Dimethyl ether of tubocurarine iodide (IV). 0.15 g of the base, O,O'-dimethylchondodendrine (XVI) was boiled for 3 hours with 5 ml of methyl alcohol and 2 ml of methyl iodide. The solution was concentrated in vacuum and the residue treated with dry ether. The yield was 0.098 g (42.1%). The m. p. was 257-258.5° (from alcohol).

λ_{\max} (alcohol) 225, 280 m μ ($\lg \epsilon$ 4.5090, 4.0426); λ_{\max} 260 m μ ($\lg \epsilon$ 3.8353).

Found %: C 49.50; H 5.41; N 3.07. $C_{40}H_{48}O_8N_2I_2 \cdot 3H_2O$. Calculated %: C 50.00; H 5.59; N 2.92.

The substance isolated did not depress the melting point of a natural sample. The m. p. was 262-264°.

λ_{\max} (alcohol) 225, 280 m μ ($\lg \epsilon$ 4.7585; 4.0735); λ_{\max} 260 m μ ($\lg \epsilon$ 3.7308).

Found %: C 49.90; H 4.56.

SUMMARY

The dimethyl ether of (\pm)-tubocurarine iodide was synthesized. The ultraviolet absorption spectrum of the dimethyl ether of (\pm)-tubocurarine iodide was found to be identical with the corresponding spectrum of the dimethyl ether of natural (\pm)-tubocurarine iodide. A mixed melting point of the two samples was not depressed.

LITERATURE CITED

- [1] A. R. McIntire, Curare, its history, nature and chemical use. Chicago (1947).
- [2] H. Hofmann, Wissenschaft, Ann., 1, 352 (1952); M. D. Mashkovskii, Nature, 10, 104 (1953).
- [3] D. W. Hesselschwerdt, E. L. Rushida, and S. C. Cullen, Anesthesiology, 12, 14 (1951); W. Kalow, J. Pharm and Experim. Therap. 110, 433 (1954).
- [4] H. King, J. Chem. Soc., 1935, 1381.
- [5] H. Kondo, H. Kataoka, and K. Kigasawa, Ann. Rept. ITSUU Lab, No. 7, 37 (1956); M. F. Brundon, and H. J. H. Perry, J. Chem. Soc., 1954, 3531.
- [6] L. V. Volkova, O. N. Tolkachev and N. A. Preobrazhenskii, Proc. Acad. Sci. USSR, 102, 521 (1955).
- [7] G. Hahn and K. Stiehl, Ber., 71, 2154 (1938).

Received February 14, 1958

INVESTIGATION OF ETHERS WITH A DOUBLE BOND IN THE ALLYL POSITION

IV. PREPARATION OF SOME ETHERS OF 2-METHYL-4-BENZYL-PENTEN-2-OL-4 AND 1-PHENYLBUTEN-1-OL-3

V. I. Pansevich-Kolyada and B. K. Bogush

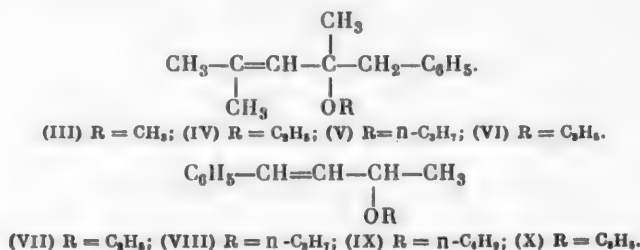
White Russian Polytechnic Institute

In previous communications [1-3] it was shown that $\alpha, \alpha, \gamma, \gamma$ -tetraalkyl substituted allyl alcohols react with primary alcohols in the presence of a small amount of dilute sulfuric acid with unusual ease to form ethers.

It is known that the etherification of certain tertiary alcohols with phenyl or styryl radicals at the alcohol group also proceeds very readily [4-14]. Therefore, it seemed interesting to investigate the esterification of tetrasubstituted allyl alcohols with aryl radicals.

The present communication is the result of our work on the etherification of 2-methyl-4-benzylpenten-2-ol-4 (I) and 1-phenylbuten-1-ol-3 (trans-methylstyrylcarbinol) (II) with methyl, ethyl, n-propyl, n-butyl and allyl alcohols in the presence of sulfuric acid. It was thus established that alcohol (I) etherified with almost the same ease as tetraalkyl-substituted allyl alcohols [1-3], but, as we noted previously [1], alcohol (II) formed ethers with much more difficulty. The difference in the etherification rates of alcohol (I and II) is undoubtedly explained by the difference in the nature of the alcohol group.

The ethers obtained have the following structure:



The physical constants and analytical data are presented in the Table. 1-Phenyl-3-ethoxybutene-1 was oxidized with 1% potassium permanganate solution. The presence of benzaldehyde and benzoic acid in the oxidation products was established. The other oxidation products were not isolated.

EXPERIMENTAL

2-Methyl-4-benzylpenten-2-ol-4 (I) was synthesized from benzylmagnesium chloride and mesitylene oxide [15, 16].

B. p. 120-122° (9 mm), n_D^{20} 1.5186, d_4^{20} 0.9645, M_R 59.75; calc. 59.69.

2-Methyl-4-benzyl-4-methoxypentene-2 (III). 7 g of alcohol (I) was dissolved in 15 ml of methyl alcohol and 5 ml of 15% sulfuric acid added. After 8 minutes the temperature of the mixture rose by one degree (from 17 to 18°), then solution, which was homogeneous at first, rapidly became turbid and separated into two layers. The upper layer, containing the ether (III), was washed with water 3 times, the lower one extracted with ethyl ether and the ether extract added to the substance of the upper layer. The reaction product was dried with $MgSO_4$ and vacuum distilled after removal of the ether. We obtained 5.5 g (78.5%) of a mobile, colorless liquid with the smell of mushrooms.

Characteristics of Ethers Obtained

Name of ether	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D		Found %		Calc. %	
				found	calc.	C	H	C	H
2-Methyl-4-benzyl-4-methoxypentene-2 (III) $C_{14}H_{20}O$	104—108°(2)	1.5169	0.9496	64.98	64.43	82.51	9.78	82.35	9.86
2-Methyl-4-benzyl-4-ethoxypentene-2 (IV) $C_{15}H_{22}O$	105—109 (2)	1.5218	0.9520	69.59	69.04	82.91	9.87	82.52	10.16
2-Methyl-4-benzyl-4-n-propoxypentene-2(V) $C_{16}H_{24}O$	123—124 (4)	1.5181	0.9423	74.57	73.66	83.06	10.14	82.76	10.34
2-Methyl-4-benzyl-4-allyloxypentene-2 (VI) $C_{16}H_{22}O$	114—115 (2.5)	1.5241	0.9611	73.23	73.20	83.26	9.77	83.47	9.56
1-Phenyl-3-ethoxybutene-1 (VII) $C_{12}H_{16}O$	85—86 (1.5)	1.5302	0.9515	57.15	55.19	81.80	8.93	81.81	9.09
1-Phenyl-3-n-propoxybutene-1 (VIII) $C_{13}H_{18}O$	96—97 (2.5)	1.5276	0.9521	61.40	59.81	82.28	9.27	82.10	9.47
1-Phenyl-3-n-butoxybutene-1 (IX) $C_{14}H_{20}O$	110—111.5 (2.5)	1.5309	0.9536	66.16	64.43	82.25	9.57	82.35	9.80
1-Phenyl-3-allyloxybutene-1 (X) $C_{13}H_{16}O$	93—94 (1.5)	1.5409	0.9717	60.62	59.34	83.00	8.83	82.98	8.51

2-Methyl-4-benzyl-4-ethoxypentene-2 (IV). To a solution of 10 g of alcohol (I) in 20 ml of ethyl alcohol was added 5 ml of 15% sulfuric acid. After 7 minutes the temperature of the homogeneous mixture rose from 17 to 19°, then the solution rapidly became turbid and separated into two layers. After processing as in the previous experiment, the reaction products were distilled in vacuum. We obtained 6 g of a colorless, mobile liquid, smelling of mushrooms. The yield of ether was 60%.

2-Methyl-4-benzyl-4-propoxypentene-2 (V). 10 g of alcohol (I) was dissolved in 16.5 g of n-propyl alcohol and then 5 ml of sulfuric acid (1:5) added. The mixture acquired an orange color and the temperature rose from 16 to 17°. Over night the mixture separated into two layers. Processing as in the previous experiments and distillation yielded 4.8 g (48%) of ether (V) as a mobile, straw-colored liquid with the smell of mushrooms.

2-Methyl-4-benzyl-4-allyloxypentene-2 (VI). To a solution of 10 g of alcohol (I) in 10 g of allyl alcohol was added 2 ml of sulfuric acid (1:5). The temperature of the mixture rose by 1° and two layers were formed. Distillation yielded 6.5 g (65%) of a mobile, slightly yellowish liquid with the smell of mushrooms.

1-Phenylbuten-1-ol-3 (trans-methylstyrylcarbinol) (II) was synthesized from methylmagnesium chloride and cinnamaldehyde [17].

B. p. 116-117° (13 mm), n_D^{20} 1.5322, d_4^{20} 1.0090, MR_D 45.46; calc. 45.83.

1-Phenyl-3-ethoxybutene-1 (VII). Into a solution of 15 g of alcohol (II) in 30 g of ethyl alcohol was added 12 ml of 33% sulfuric acid in small portions. The mixture heated up from 18 to 23°, but did not separate into layers. After two days a further 1.5 ml of 50% sulfuric acid was added and then an upper ether layer separated. We isolated 9.8 g (59%) of ether (VII) as a slightly yellowish, mobile liquid.

1-Phenyl-3-propoxybutene-1 (VIII). 10 g of 1-phenylbuten-1-ol-3 (II) and 12 g of n-propyl alcohol were mixed and 13.5 ml of 33% sulfuric acid added. The temperature of the mixture rose from 19-26° and after 1 hour the solution became turbid and separated into layers. The normal treatment yielded 7.3 g (58%) of the ether in the form of a mobile, slightly yellowish liquid with a weak flower-like smell.

1-Phenyl-3-butoxybutene (IX). 10 g of alcohol (II), 15 g of n-butyl alcohol and 14 ml of 33% sulfuric acid were used. The temperature rose from 19 to 23° and after a day, two layers formed. We isolated 6.5 g (52%) of the ether in the form of a yellowish liquid with a pleasant smell.

1-Phenyl-3-allyloxybutene-1 (X). To a solution of 10 g of alcohol (II) in 12 g of allyl alcohol was added 8 ml of 33% sulfuric acid. The temperature rose from 19 to 24° and the solution became turbid and separated into layers. The ether was extracted, dried with $MgSO_4$ and vacuum distilled. We obtained 6.9 g (58%) of a yellowish liquid with a pleasant smell.

Oxidation of 1-phenyl-3-ethoxybutene-1 (VII). 5 g of ether was emulsified in 100 ml of water and 800 ml of 1% potassium permanganate solution gradually added. The oxidation products were treated by the usual method. From the solution containing the neutral, volatile substances, 15 ml of distillate was distilled into a solution of semicarbazide. Fine crystals of a semicarbazone with m. p. 216° rapidly separated. A mixed melting point with the semicarbazone of benzaldehyde was not depressed. The solution of volatile acids was treated with Ag_2CO_3 . However, it was not possible to obtain pure silver salts of the acids, as the silver was rapidly reduced. The involatile acids were extracted with ether. Removal of ether yielded a sublimable, crystalline substance, which melted at 121.7°. A mixture with benzoic acid melted at the same temperature.

SUMMARY

1. 2-Methyl-4-benzylpenten-2-ol-4 and 1-phenylbuten-1-ol-3 (trans-methylstyrylcarbinol) were etherified with methyl, ethyl, n-propyl, n-butyl and allyl alcohols.
2. We obtained 8 previously undescribed ethers with a double bond in the allyl position.

LITERATURE CITED

- [1] V. I. Pansevich-Kolyada, Z. B. Idel'chik, and L. A. Kureichik, J. Gen. Chem. 25, 1481 (1955).*
- [2] V. I. Pansevich-Kolyada and L. F. Osipenko, J. Gen. Chem. 28, 641, 909 (1958).*
- [3] V. I. Pansevich-Kolyada and I. F. Osipenko, J. Gen. Chem. 28, 929 (1958).*
- [4] Ramdohr, J. Chem. Soc. 1858, 447.
- [5] Linnemann, Lieb. Ann., 133, 14 (1865).
- [6] Borbier, Ann. Chim. [5] 7, 507 (1876).
- [7] Nef, Lieb. Ann. 298, 235 (1897).
- [8] Stobbe, Ber. 34, 1967 (1901).
- [9] Knoevenagel and Heckel, Ber. 36, 2823 (1903).
- [10] Ziegler and Tripp, Lieb. Ann., 434, 34 (1923).
- [11] Ziegler and Tripp, Ber. 57, 420 (1924).
- [12] Ziegler, Richter, and Schnell, Lieb. Ann., 437, 227, 240 (1924).
- [13] Ziegler, Grabbe, and Ulrich, Ber., 57, 1986 (1924).

*Original Russian pagination. See C.B. Translation.

[14] Senderens, C. r., 182, 612 (1926).

[15] Fellenberg, Ber., 39, 2064 (1906).

[16] V. I. Pansevich-Kolyada and V. A. Ablova, J. Gen. Chem. 24, 493 (1954).*

[17] Synth. Org. Preps., IV, 504 (1953).

Received March 6, 1958

* Original Russian pagination. See C.B. Translation.

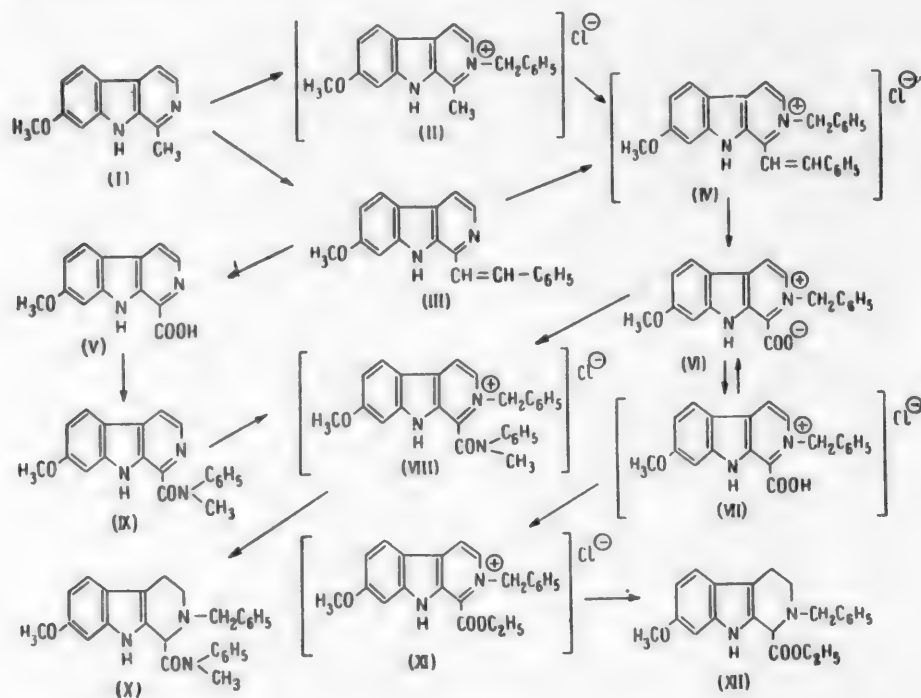
SYNTHESIS OF DERIVATIVES OF Py-N-BENZYL TETRAHYDRONORHARMINE-3-CARBOXYLIC ACID

L. N. Yakhontov and M. V. Rubtsov

S. Ordzhonikidze All-Union Chemicopharmacological Scientific Research Institute

Esters and amides of Py-tetrahydronorharmine-3-carboxylic acid are of interest as intermediates for the synthesis of analogs of reserpine. Due to preparative difficulties, however, these compounds have not previously been described. It has merely been reported in the literature [1] that esters of Py-tetrahydronorharmine-3-carboxylic acid are formed in low yields.

Our earlier general method [2] of reduction of derivatives of harmine to derivatives of Py-tetrahydronorharmine with the help of sodium borohydride enabled the synthesis of the ethyl ester (XI) and the N-methyl-anilide (X) of Py-N-benzyltetrahydronorharmine-3-carboxylic acid, starting from the Py-N-benzyl chloride of norharmine-3-carboxylic acid (VII) or its betaine (VI) and proceeding via the ethyl ester (XI) and the N-methyl-anilide (VIII).



Originally the Py-N-benzyl chloride of norharmine-3-carboxylic acid appeared to be obtained most conveniently by the reaction of norharmine-3-carboxylic acid [3] (V) with benzyl chloride. Preliminary experiments showed, however, that norharmine-3-carboxylic acid remains unchanged when heated with benzyl chloride

in benzyl alcohol to 120°. Further rise of temperature leads to the start of decarboxylation with formation of the Py-quaternary salt. In the 120-160° temperature range a mixture of norharmine Py-N-benzyl chloride and the original norharmine-3-carboxylic acid is formed. At 160° the main product of the reaction (yield 53%) is norharmine Py-N-benzyl chloride. For this reason we used 3-styrylnorharmine (IV) for the synthesis of norharmine-3-carboxylic acid Py-N-benzyl chloride. The styryl derivative was prepared from harmine (I) by two routes. By one route, 3-styrylnorharmine (III) was obtained by reaction of harmine with benzaldehyde [3] followed by treatment with benzyl chloride in a medium of benzyl alcohol for 13 hr at 160°. By the second route harmine was treated with benzyl chloride to give harmine Py-N-benzyl chloride [2] (II), and this was reacted with benzaldehyde for 1 hr in presence of piperidine at a gentle boil. The yield of 3-styrylnorharmine Py-N-benzyl chloride (IV) by the first route is 46% (calculated on the harmine), and that by the second route is 58.8%. An attempt was made to obtain 3-styrylnorharmine Py-N-benzyl chloride directly from harmine by simultaneous treatment with benzyl chloride and benzaldehyde, but a difficultly separable mixture of products was obtained.

3-Styrylnorharmine Py-N-benzyl chloride was oxidized by potassium permanganate in acetone. The products of oxidation came down from solution with the manganese dioxide. The precipitate was treated with sodium bisulfite and 10% sulfuric acid and then subjected to extraction for removal of the benzoic acid. In this manner a substance was isolated which was free of chloride or sulfate ions, was insoluble in caustic alkalies, and did not titrate with alcoholic alkali. Its chemical properties and analytical data indicate that it is an inner salt — the betaine of Py-N-benzylnorharmine-3-carboxylic acid (VI). The structure of the betaine was confirmed by conversion, on heating with concentrated hydrochloric acid, into norharmine-3-carboxylic acid Py-N-benzyl chloride (VII). Heating of the latter with water led to facile cleavage of a molecule of hydrogen chloride with formation of the betaine of Py-N-benzylnorharmine-3-carboxylic acid (VI). The hydrogen chloride was quantitatively determined in aqueous solution.

Norharmine-3-carboxylic acid Py-N-benzyl chloride reacts with thionyl chloride with facile formation of the acid chloride; treatment of the latter with anhydrous alcohol gives the ethyl ester of norharmine-3-carboxylic acid Py-N-benzyl chloride (XI).

Reaction of the betaine of Py-N-benzylnorharmine-3-carboxylic acid with N-methylaniline and phosphorus oxychloride at 160-170° for one-and-a-half hours led to the N-methylanilide of norharmine-3-carboxylic acid Py-N-benzyl chloride (VIII) in 72% yield. This transformation was additional proof of the structure of the betaine (VI). The N-methylanilide of norharmine-3-carboxylic acid Py-N-benzyl chloride (VIII) was also obtained from norharmine-3-carboxylic acid. Treatment of the latter with N-methylaniline in presence of phosphorus oxychloride at 160-170° gave the N-methylanilide of norharmine-3-carboxylic acid (IX) in 76% yield. This is evidently a general method of synthesis of substituted amides of norharmine-3-carboxylic acid, and is of interest because an obstacle to the preparation of these amides via esters or the acid chloride of norharmine-3-carboxylic acid is the difficult accessibility of the latter compounds [1]. The hydrochloride of the N-methylanilide of norharmine-3-carboxylic acid easily forms a monohydrate which loses its crystal water only after prolonged (36 hr) heating in vacuo at 120° over phosphorus pentoxide. Reaction of norharmine-3-carboxylic acid N-methylanilide with benzyl chloride gave norharmine-3-carboxylic acid N-methylanilide-Py-N-benzyl chloride (VIII) in 93% yield.

Reduction of the pyridine ring in the N-methylanilide (VIII) and in the ethyl ester (XI) of norharmine-3-carboxylic acid Py-N-benzyl chloride was effected with sodium borohydride in the same lines as our previous reduction [3] of harmine and norharmine Py-N-benzyl chlorides. The reactions gave the N-methylanilide (X) and the ethyl ester (XII) of Py-N-benzyltetrahydronorharmine-3-carboxylic acid in yields of 99 and 74%, respectively.

EXPERIMENTAL

3-Styrylnorharmine Py-N-benzyl chloride (IV). 1) 5.4 g 3-styrylnorharmine and 2.48 g benzyl chloride were heated 13 hr at 160° in 20 ml benzyl alcohol. During the reaction the whole of the 3-styrylnorharmine went into solution. Yellow crystals came down on cooling (weight 5.5 g, m. p. 226-230°). Treatment of the mother liquor with 100 ml ether gave another 2 g yellow crystals with m. p. 224-230°. The compound was recrystallized from isopropyl alcohol. Yield of 3-styrylnorharmine Py-N-benzyl chloride 5.75 g (75.1%). Yellow

crystals with m.p. 233-234°. Soluble in chloroform, methyl alcohol, hot isopropyl alcohol; insoluble in ether, acetone, benzene, toluene and water.

Found %: C 75.87; H 5.01; N 6.81, 6.73; Cl⁺ 8.35, 8.17. $C_{27}H_{23}ON_2Cl$. Calculated %: C 75.97; H 5.39; N 6.56; Cl⁺ 8.32.

2) 8.1 g harmine Py-N-benzyl chloride, 40 ml distilled benzaldehyde and 3 drops piperidine were heated at a gentle boil for 1 hr. During the reaction the whole of the harmine Py-N-benzyl chloride went into solution. Yellow crystals came down on cooling. Weight 8.2 g, m. p. 228-231°. Recrystallization from isopropyl alcohol gave 6.32 g (61.9%) 3-styrylnorharmine Py-N-benzyl chloride. M. p. 233-234°. No depression of melting point in admixture with the product of reaction of 3-styrylnorharmine with benzyl chloride.

Betaine of Py-N-benzylnorharmine-3-carboxylic acid (VI). 2.9 g potassium permanganate was stirred portionwise in the course of 2 hr into a suspension of 2.4 g 3-styrylnorharmine Py-N-benzyl chloride in 50 ml acetone at room temperature. The precipitate was filtered, and washed with acetone and then with methyl alcohol until the original 3-styrylnorharmine Py-N-benzyl chloride had been completely removed (i.e. until the methanol filtrate was nearly colorless). The residue was treated with saturated sodium bisulfite solution and then with 10% sulfuric acid until the manganese dioxide had been completely decomposed to water-soluble salts of divalent manganese. The remaining yellow precipitate, consisting of the betaine of Py-N-benzylnorharmine-3-carboxylic acid (with little benzoic acid) was filtered and washed with water. Yield 0.96 g (51.3%). Light-yellow crystals, insoluble in water, ether, acetone, benzene, dioxane, chloroform, toluene and alcohol; soluble in boiling methanol (1 : 200); m. p. 210-211°. Negative reaction for halogen (Beilstein) and sulfur (test with lead acetate after fusion with metallic sodium); insoluble in aqueous solutions of acids and caustic alkalies.

Found %: C 72.10, 72.22; H 4.98, 4.84; N 8.38, 8.41. $C_{20}H_{16}O_3N_2$. Calculated %: C 72.28; H 4.82; N 8.43.

Norharmine-3-carboxylic acid N-methylanilide (IX). 1.5 g phosphorus oxychloride was added to a mixture of 3 g norharmine-3-carboxylic acid and 10 g N-methylaniline. Considerable heat was developed and the mixture darkened. After heating at 160-170° for 1.5 hr, the mixture was dissolved in 100 ml methanol and acidified with concentrated hydrochloric acid until the liquid had an acid reaction to congo. Rubbing with a small glass rod led to separation of the monohydrate of norharmine-3-carboxylic acid N-methylanilide hydrochloride. Weight 3.65 g (76%). Light-yellow crystals with m. p. 192-193° (from isopropyl alcohol). Soluble in alcohols, insoluble in other common organic solvents and in water.

Found %: C 62.34; H 5.45; N 10.59; Cl⁺ 9.25. $C_{20}H_{17}O_2N_3 \cdot HCl \cdot H_2O$. Calculated %: C 62.28; H 5.19; N 10.89; Cl⁺ 9.21.

The compound loses its crystal water when heated 36 hr in vacuo at 120°. Anhydrous norharmine-3-carboxylic acid N-methylanilide hydrochloride forms yellow crystals with m. p. 192-193°.

Found %: C 65.30; H 5.14; N 11.72; Cl⁺ 9.83. $C_{20}H_{17}O_2N_3 \cdot HCl$. Calculated %: C 65.30; H 4.89; N 11.43; Cl⁺ 9.66.

2.2 g norharmine-3-carboxylic acid N-methylanilide hydrochloride was treated at room temperature with 20 ml saturated aqueous ammonia. The reaction mass was stirred 1 hr. The color of the precipitate changed from yellow to white. The norharmine-3-carboxylic acid N-methylanilide base was filtered off. Weight 1.85 g (98%). Colorless crystals, m. p. 149-150°; soluble in acetone, alcohols, benzene and toluene; poorly soluble in water, ether and xylene.

Found %: C 72.35, 72.64; H 5.33, 5.42; N 12.48. $C_{20}H_{17}O_2N_3$. Calculated %: C 72.50; H 5.14; N 12.68.

Norharmine-3-carboxylic acid Py-N-benzyl chloride N-methylanilide (VIII). 1) A solution of 0.8 g norharmine-3-carboxylic acid N-methylanilide and 0.37 g benzyl chloride in 10 ml benzyl alcohol was heated 13 hr at 180°. The reaction mass acquired an emerald-green color. After 7 ml benzyl alcohol had been distilled off in vacuo, the residue was treated with 50 ml ether. The resulting precipitate was washed with benzene and ether. Yield of tetrahydrate of norharmine-3-carboxylic acid Py-N-benzyl chloride N-methylanilide 1.09 g (93%). Yellow crystals, rapidly turning green in the air; m. p. 147-148° (decomp.). Soluble in chloroform and alcohols; poorly soluble in water, benzene, toluene and ether.

Found %: N 7.99, 7.70; Cl⁺ 6.79. $C_{27}H_{24}O_2N_2Cl \cdot 4H_2O$. Calculated %: N 7.92; Cl⁺ 6.71.

2) 1 g phosphorus oxychloride was added to a mixture of 1 g betaine of Py-N-benzylnorharmine-3-carboxylic acid and 3.3 g N-methylaniline. The reaction mass developed considerable heat and darkened. After heating 1.5 hr at 160-170°, the green, viscous mass was dissolved in 7 ml methanol and treated with 5 ml concentrated hydrochloric acid until acid to congo. The mass remained homogeneous on standing and on being rubbed with a glass rod. 40 ml water was added. The resulting oily precipitate crystallized when triturated in presence of benzene. The solid was washed with benzene and ether. Yield of tetrahydrate of norharmine-3-carboxylic acid Py-N-benzyl chloride N-methylanilide 1.15 g (72%). Yellow crystals, quickly turning green in the air, m. p. 147-148° (decomp.). No depression of melting point in admixture with the product of reaction of norharmine-3-carboxylic acid N-methylanilide with benzyl chloride.

Py-N-benzyltetrahydronorharmine-3-carboxylic acid N-methylanilide (X). To a solution of 0.5 g tetrahydrate of norharmine-3-carboxylic acid Py-N-benzyl chloride N-methylanilide in 5 ml methanol was added 0.6 g sodium borohydride portionwise in the course of 10 min. The reaction mixture frothed and developed heat. After the whole of the sodium borohydride had been added, the green solution turned yellow. Stirring was continued at room temperature for another 2.5 hr, and this was followed by addition of 20 ml 50% aqueous potassium carbonate. The Py-N-benzyltetrahydronorharmine-3-carboxylic acid N-methylanilide was extracted with benzene. The benzene solution was twice extracted with water to remove methyl alcohol. It was then dried with potassium carbonate. The benzene was distilled off and the residue was washed with ligroine. Yield of Py-N-benzyltetrahydronorharmine-3-carboxylic acid N-methylanilide 0.4 g (99%). Colorless crystals, m.p. 172-173° (from methanol). Readily soluble in benzene, chloroform, acetone and ethanol; less soluble in ether and methanol; insoluble in ligroine and water.

Found %: C 75.90, 76.17; H 6.63, 6.25; N 9.48, 9.64. $C_{27}H_{27}O_2N_2$. Calculated %: C 76.24; H 6.36; N 9.88.

Norharmine-3-carboxylic acid Py-N-benzyl chloride (VII). 1 g betaine of Py-N-benzylnorharmine-3-carboxylic acid was treated with 120 ml boiling concentrated hydrochloric acid. After 5-minutes' boiling, the hot solution was filtered. On cooling, it deposited yellow crystals of norharmine-3-carboxylic acid Py-N-benzyl chloride. Yield 0.85 g (76.5%). M. p. 161° (decomp.) (on continued heating the compound again melts at 210-211°). Soluble in methyl and ethyl alcohols, less soluble in acetone, insoluble in water, ether, chloroform, benzene and toluene.

Found %: C 64.93; H 4.69; N 7.44, 7.39; Cl⁺ 9.59. $C_{20}H_{17}O_3N_2Cl$. Calculated %: C 65.12; H 4.61; N 7.59; Cl⁺ 9.63.

Transformation of norharmine-3-carboxylic acid Py-N-benzyl chloride (VII) into the betaine of Py-N-benzylnorharmine-3-carboxylic acid (VI). A suspension of 0.2 g norharmine-3-carboxylic acid Py-N-benzyl chloride in 10 ml distilled water was boiled 1 hr. The solid did not dissolve but lightened considerably in color. It was filtered and washed with distilled water. There was obtained 0.16 g (90%) of the betaine of Py-N-benzylnorharmine-3-carboxylic acid. Light-yellow crystals, m. p. 210-211°. No depression of melting point in admixture with the betaine obtained by oxidation of 3-styrylnorharmine Py-N-benzyl chloride with potassium permanganate. The aqueous solution and the wash water were combined and analyzed for chloride ion by Volhard titration.

Found Cl⁺ 0.019 g. Calculated Cl⁺ 0.019 g.

Ethyl ester of norharmine-3-carboxylic acid Py-N-benzyl chloride (XI). 50 ml of purified thionyl chloride was added to 5.25 g norharmine-3-carboxylic acid Py-N-benzyl chloride. Rapid solution occurred with foaming and darkening of the solution. The reaction mass was heated 1.5 hr at 45-50°. The resulting solution was evaporated in vacuo; residues of thionyl chloride were removed by two additions of anhydrous benzene followed by distillation in vacuo. The norharmine-3-carboxylic acid Py-N-benzyl chloride acid chloride was heated at the boil with 50 ml anhydrous ethyl alcohol for 5 hr. The solution was then evaporated in vacuo and the residue was dissolved in chloroform. The solution was filtered and diluted with ether to give a precipitate which was recrystallized from 3 liters dioxane. Yield of ethyl ester of norharmine-3-carboxylic acid Py-N-benzyl chloride 4.57 g (81%). Yellow crystals with m. p. 141-142° (decomp.). Readily soluble in chloroform and alcohols, soluble in boiling dioxane (1:625), insoluble in ether, acetone, water and cold dioxane.

Found %: C 66.33, 66.63; H 5.07, 5.31; N 6.81, 6.97; Cl⁺ 8.90, 8.69. $C_{22}H_{24}O_3N_2Cl$. Calculated %: C 66.58; H 5.08; N 7.06; Cl⁺ 8.95.

Ethyl ester of Py-N-benzyltetrahydronorharmine-3-carboxylic acid (XII). To a solution of 0.2 g ethyl ester of norharmine-3-carboxylic acid Py-N-benzyl chloride in 10 ml ethyl alcohol was added portionwise 0.2 g sodium borohydride in the course of 15 min. The reaction mass was diluted with 50 ml water. The resulting precipitate (0.17 g) was filtered, dried, and dissolved in ether. The ethereal solution was treated with alcoholic hydrogen chloride to give 0.15 g (74%) of the hydrochloride of the ethyl ester of Py-N-benzyltetrahydronorharmine-3-carboxylic acid. Yellow crystals, m. p. 150-151° (decomp.). Readily soluble in alcohol, less soluble in acetone and chloroform, insoluble in ether, benzene and water.

Found %: C 65.95; H 6.41; N 7.08, 6.85; Cl⁺ 8.97, 9.04. $C_{22}H_{24}O_3N_2 \cdot HCl$. Calculated %: C 65.92; H 6.24; N 6.99; Cl⁺ 8.86.

SUMMARY

1. The ethyl ester and N-methylanilide of Py-N-benzyltetrahydronorharmine-3-carboxylic acid, not previously described in the literature, were synthesized.
2. It was shown that oxidation of 3-styrylnorharmine Py-N-benzyl chloride with potassium permanganate gives the betaine of Py-N-benzylnorharmine-3-carboxylic acid.
3. A method of preparation of amides of norharmine-3-carboxylic acid is based on reaction of norharmine-3-carboxylic acid with amines in presence of phosphorus oxychloride at 160-170°.

LITERATURE CITED

- [1] N. L. Koretskaya, A. V. Danilova, and L. M. Utkin, J. Gen. Chem., 27, 542 (1957).*
- [2] W. H. Perkin and R. Robinson, J. Chem. Soc. 1912, 1775.
- [3] L. N. Yakhontov and M. V. Rutsov, J. Gen. Chem. 28, 3108 (1958).

Received March 21, 1958

* Original Russian pagination. See C.B. Translation.

THE STEREOCHEMISTRY OF THE SYMMETRIZATION OF SOME ORGANOMERCURY DERIVATIVES OF CAMPHOR UNDER THE ACTION OF HYDRAZINE HYDRATE

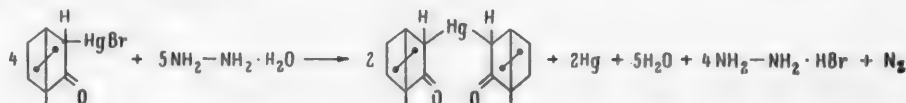
O. A. Reutov and Lu Ching-chu

Moscow State University

Following an investigation of the symmetrization of 3-bromomercuricamphor under the action of sodium thiosulfate [1], we have undertaken a study of the stereochemistry of the same reaction under the action of hydrazine hydrate.

Our previously prepared diastereomers [1], 3-bromomercuri-L-camphor and 3-bromomercuri-D-camphor, have the following constants: (I) m. p. 222-223° and $[\alpha]^{18}_D -30.7 \pm 1.2$; (II) m. p. 216-218° and $[\alpha]^{18}_D -126 \pm 1.9$; (III) m. p. 222-223° and $[\alpha]^{18}_D +28.7 \pm 1.2$; (IV) m. p. 216-218° and $[\alpha]^{18}_D +126.3 \pm 1.7$.

We made a study of the action of hydrazine hydrate on the diastereomers (I), (II) and (III). The reaction goes in accordance with the equation



Symmetrization of diastereoisomer (I) of 3-bromomercuri-L-camphor with $[\alpha]^{18}_D -29.5 \pm 1.1$ was performed under the action of a twofold excess of hydrazine hydrate in dioxane in the cold for 30 min. Water was added to the filtrate following separation of the insoluble solid. The precipitated bis(camphor)mercury was filtered off and washed with water. After recrystallization from aqueous dioxane it had m. p. 205-210° (decomp.) and $[\alpha]^{18}_D -86.3 \pm 2.1$.

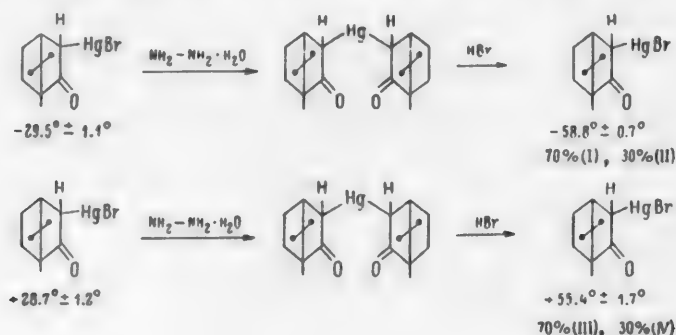
Reaction of the unrecrystallized bis(L-camphor)mercury with an equimolar quantity of hydrogen bromide (alcoholic solution) gave a mixture of the diastereomers (I) and (II) of 3-bromomercuri-L-camphor. After it had been washed with water and ether, the mixture had m. p. 195-205° and $[\alpha]^{18}_D -65.8 \pm 1.3$. After recrystallization from aqueous dioxane it had m. p. 220-222° and $[\alpha]^{18}_D -58.8 \pm 0.7$.

The diastereoisomer (III) of 3-bromomercuri-D-camphor with $[\alpha]^{18}_D +28.7 \pm 1.2$ was symmetrized with hydrazine hydrate under identical conditions. Reaction of the unrecrystallized bis(D-camphor)mercury with an equimolar quantity of hydrogen bromide (alcoholic solution) gave a mixture of diastereomers (III) and (IV) with m. p. 219-220° and $[\alpha]^{18}_D +55.4 \pm 1.7$ (after washing with water and ether).

The magnitude of the angle of rotation of mixtures of organomercury salts formed by the action of HBr on bis(L-camphor)mercury and bis(D-camphor)mercury indicates that one of them consists of approximately 70% diastereomer (I) and 30% diastereomer (II), while the second consists of 70% diastereoisomer (III) and 30% diastereomer (IV).

It is an interesting fact that symmetrization of the less stable diastereomer (II) of 3-bromomercuricamphor gives the same bis(L-camphor)mercury as is formed in the symmetrization of diastereomer (I). This is

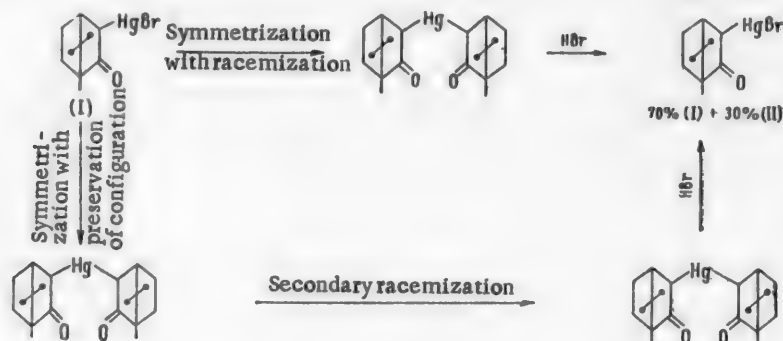
evident from the fact that treatment of bis(L-camphor)mercury with hydrogen bromide gives about 70% of diastereomer (I) and 30% of diastereomer (II). A possible explanation of this phenomenon is that the less stable diastereomer (II) is transformed into the more stable (I) under action of hydrazine hydrate (a basic substance), so that diastereomer (I) already enters into the symmetrization reaction. The reaction of a deficiency of



hydrazine hydrate on diastereomer (II) with $[\alpha]_D^{25} -123^\circ \pm 1.8^\circ$ does indeed yield 3-bromomercuri-L-camphor with $[\alpha]_D^{25} -73.1^\circ \pm 2.5^\circ$, i.e. a nearly equimolar mixture of diastereomers (I) and (II). On the other hand when a deficiency of hydrazine hydrate acts on diastereomer (I) with $[\alpha]_D^{25} -30.7^\circ \pm 1.2^\circ$, the nonreacting L-camphor-3-mercuribromide has $[\alpha]_D^{25} -38.9^\circ \pm 3.7^\circ$, i.e. it is substantially the pure diastereomer (I). Consequently, diastereomer (I) differs from diastereomer (II) in not undergoing racemization* under the action of hydrazine hydrate.

Previously [2] we regarded the formation of a mixture of stereoisomers (I) and (II) (70 and 30%) and a mixture of stereoisomers (III) and (IV) (70 and 30%) when hydrogen bromide acted on bis(L-camphor)mercury and bis(D-camphor)mercury (obtained from the pure diastereomers (I) and (III), respectively) as evidence in favor of a homolytic mechanism of symmetrization under the action of hydrazine hydrate. In this respect we supported the hypothesis of Wright [3].

It was found, however, that bis(camphor)mercury itself undergoes racemization under the action of hydrazine hydrate. For example, bis(L-camphor)mercury, formed by symmetrization of pure diastereomer (I) by sodium thiosulfate (with preservation of configuration) and forming pure diastereomer (I) on treatment with HBr [1], no longer gives pure diastereomer (I) under the action of HBr after 30-minutes' contact with traces of hydrazine hydrate in dioxane, but a mixture of the diastereomers (I) and (II) with $[\alpha]_D^{25} -64.0^\circ \pm 1.5^\circ$.

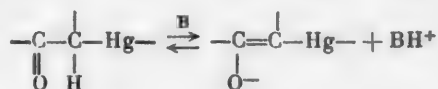


Consequently the stereoisomeric result of symmetrization of diastereomer (I) of 3-bromomercuri-L-camphor by hydrazine hydrate can be due either to the reaction proceeding with racemization or to it proceeding

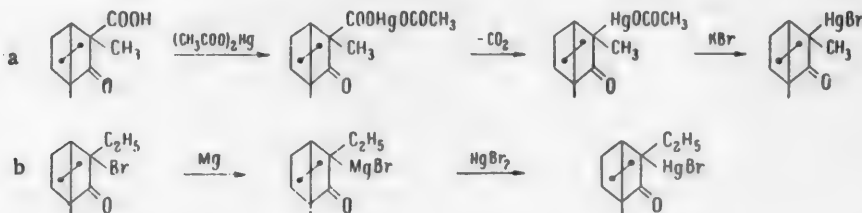
* Here and in all other cases the terms "racemization" and "retention of configuration" relate to the asymmetric carbon atom linked to the mercury.

with preservation of configuration but with secondary racemization of the symmetrical product under the action of hydrazine hydrate.*

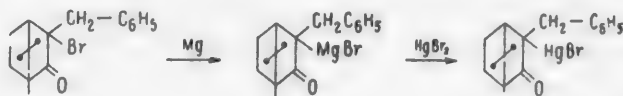
The facile racemization of 3-bromomercuricamphor and bis(camphor)mercury is evidently due to the presence of α -hydrogen atoms which easily split off in the form of protons under the action of basic substances.



In order to clarify the stereochemistry of symmetrization under the action of hydrazine hydrate, it was therefore natural that we should consider making use of organomercury salts which contained alkyl groups instead of an α -hydrogen atom. With this objective we synthesized 3-methyl-3-bromomercuri-L-camphor and 3-ethyl-3-bromomercuri-L-camphor.



Both of these compounds, however, proved to be extremely unstable. They decomposed even on standing in the air. They could therefore be used for our purpose. On the other hand, 3-benzyl-3-bromomercuri-L-camphor was found to be perfectly stable.** It was prepared by the reactions:



Unfortunately, 3-benzyl-3-bromomercuricamphor appears to exist only in the form of one diastereomer with m. p. 118-120° and $[\alpha]_D^{25} +10.6 \pm 0.9^\circ$. Not even traces of the second isomer could be isolated.

For the reasons set forth above, we were unable to make use of 3-alkyl-3-bromomercuri- derivatives of camphor for a study of the stereochemistry of the symmetrization reaction under the action of hydrazine hydrate.

In the circumstances we were compelled to resort to organomercuric derivatives of camphane which are not α -mercurated oxo compounds. Results of the study of the stereochemistry of symmetrization reactions of these substances will be presented in the next communication.

* Another possibility that cannot be excluded is the superposition of the two processes — racemization during the symmetrization reaction and subsequent secondary racemization of the resulting bis(camphor)mercury.

** The mercury in 3-benzyl-3-bromomercuricamphor is extraordinarily labile. It splits off under the action of dilute hydrochloric acid in the cold and of acetic acid when heated. The only suitable symmetrizing agent for this compound was ammonia in chloroform. Symmetrization yields a single isomer of the organomercury compound with m. p. 150-153° (decomp.) and $[\alpha]_D^{25} -31.5^\circ \pm 1.6^\circ$ (after recrystallization from ethyl alcohol). 3-Benzyl-3-bromomercuricamphor could not be obtained from the symmetrical compound by the action of the equivalent quantity of dilute alcoholic solution of hydrogen bromide, since both the symmetrical and the unsymmetrical compounds are very easily decomposed by HBr. All of these experiments led to a mixture of starting compound with 3-benzyl-3-bromomercuricamphor and 3-benzylcamphor.

EXPERIMENTAL

1. Symmetrization of a mixture of the diastereomers of 3-bromomercuri-L-camphor by hydrazine hydrate. 2 g 3-bromomercuri-L-camphor was stirred into a solution of 0.6 g hydrazine hydrate in 15 ml dioxane. After half an hour the metallic mercury was filtered off, and the filtrate was made up to 150 ml with water. The resulting precipitate of bis(L-camphor)-3,3'-mercury was filtered off and washed with water. Weight 0.6 g (50%). After recrystallization from 70% aqueous dioxane the decomposition point was 200-205°.

Found %: C 47.71, 47.59; H 6.00, 6.03; Hg 40.09, 40.07. $(C_{10}H_{15}O)_2Hg$. Calculated %: C 47.69; H 6.01; Hg 39.88.

2. Symmetrization of diastereomer (I) of 3-bromomercuri-L-camphor by hydrazine hydrate. 4 g of diastereomer (I) of 3-bromomercuri-L-camphor with $[\alpha]^{18}_D -29.5^\circ \pm 1.1^\circ$ was added to a solution of 1.2 g hydrazine hydrate in 15 ml dioxane. After half an hour the metallic mercury was filtered off, and the filtrate was diluted with water to 200 ml. The resulting precipitate of bis(camphor)-3,3'-mercury was filtered off and washed with water. After being dried in the air, the precipitate weighed 7.7 g (70%).

Decomp. temp. 205-210° (from 70% aqueous dioxane), $[\alpha]^{18}_D -86.3^\circ \pm 2.1^\circ$ (c 2.26, $\underline{1}$ 1.9, $\alpha -3.7^\circ \pm 0.05^\circ$).

Found %: C 47.16, 47.30; H 5.94, 6.03. $(C_{10}H_{15}O)_2Hg$. Calculated %: C 47.69; H 6.01.

After a second crystallization from aqueous dioxane the compound had $[\alpha]^{18}_D -150.3^\circ \pm 1.3^\circ$ (c 1.93, $\underline{1}$ 1.9, $\alpha -5.65^\circ \pm 0.05^\circ$). After a third crystallization from aqueous dioxane the values were $[\alpha]^{18}_D -219.7^\circ \pm 1.4^\circ$ (c 1.82, $\underline{1}$ 1.9, $\alpha -7.6^\circ \pm 0.05^\circ$). After a fourth crystallization the product had $[\alpha]^{18}_D -241.4^\circ \pm 4.3^\circ$ (c 0.612, $\underline{1}$ 1.9, $\alpha -2.8^\circ \pm 0.05^\circ$).

3. Reaction of bis(L-camphor)-3,3'-mercury (obtained by symmetrization of the diastereomer (I) of 3-bromomercuri-L-camphor with hydrazine hydrate) with hydrogen bromide. 0.5 g unrecrystallized bis(L-camphor)-3,3'-mercury (obtained by symmetrization with hydrazine hydrate of diastereomer (I) with $[\alpha]^{18}_D -29.5^\circ \pm 1.1^\circ$) was dissolved in 25 ml methyl alcohol. In the course of 20 min. 1 ml of alcoholic solution of hydrogen bromide (containing 0.09 g HBr) was added dropwise with vigorous stirring to the solution of the diastereomer. The alcohol was evaporated off and the residue was washed with water and ether (5 ml). Weight of 3-bromomercuricamphor 0.4 g (93%).

M. p. 190-205°, $[\alpha]^{18}_D -65.8^\circ \pm 1.3^\circ$ (c 2.0, $\underline{1}$ 1.9; $\alpha -2.5^\circ \pm 0.05^\circ$).

Found %: C 30.77; 31.29; H 3.99, 4.21. $C_{10}H_{14}OHgBr$. Calculated %: C 27.28; H 3.50.

M. p. after recrystallization from aqueous dioxane 220-222°; $[\alpha]^{18}_D -58.8^\circ \pm 0.7^\circ$ (c 0.313, $\underline{1}$ 1.9, $\alpha -0.35^\circ \pm 0.05^\circ$).

Found %: C 27.80, 27.81; H 3.68, 3.72. $C_{10}H_{15}OHgBr$. Calculated %: C 27.82; H 3.50.

4. Symmetrization of diastereomer (II) of 3-bromomercuri-L-camphor by hydrazine hydrate. Into a solution of 0.6 g hydrazine hydrate in 20 ml dioxane was stirred 2 g of diastereomer (II) with $[\alpha]^{18}_D -123.1^\circ \pm 1.7^\circ$. After half an hour the metallic mercury was filtered off, and the filtrate was diluted with water to a volume of 200 ml. The resulting precipitate of bis(L-camphor)-3,3'-mercury was filtered off and washed with water. Decomp. p. 190-201°. Weight 0.1 g (9%).

5. Reaction of bis(L-camphor)-3,3'-mercury (obtained by symmetrization of diastereomer (II) of 3-bromomercuri-L-camphor by hydrazine hydrate) with hydrogen bromide. 0.5 g unrecrystallized bis(camphor)-3,3'-mercury, prepared in experiment 4 by symmetrization of diastereomer (II), was dissolved in 25 ml methyl alcohol. With energetic stirring, addition was made dropwise to this solution during 30 min of 2 ml alcoholic solution of HBr containing 0.08 g HBr. The alcohol was evaporated off and the dry residue was washed with water and ether (5 ml). Weight 0.2 g (46%). M. p. 214-217°, $[\alpha]^{18}_D -66.7^\circ \pm 3.8^\circ$ (c 0.71, $\underline{1}$ 1.9, $\alpha -0.9^\circ \pm 0.05^\circ$). M. p. after recrystallization from 70% aqueous dioxane 219-221°, ($[\alpha]^{18}_D -57.5^\circ \pm 2.5^\circ$ (c 1.05, $\underline{1}$ 1.9, $\alpha -1.15^\circ \pm 0.5^\circ$).

Found %: C 28.02, 27.83; H 3.60, 3.51. $C_{10}H_{15}OHgBr$. Calculated %: C 27.82; H 3.50.

6. Symmetrization of the diastereomer (III) of 3-bromomercuri-D-camphor by hydrazine hydrate. 2 g of 3-bromomercuri-D-camphor with $[\alpha]^{18}_D +28.7^\circ \pm 1.2^\circ$ was introduced into a solution of 0.6 g hydrazine hydrate in 20 ml dioxane. The precipitated mercury was filtered off, and the filtrate was diluted with water to 200 ml. The resulting precipitate of bis(D-camphor)-3,3'-mercury was filtered and washed with water. Yield 0.5 g (45%).

M. p. 206-215° (from 70% aqueous dioxane), $[\alpha]^{18}_D +87.0^\circ \pm 1.7^\circ$ (c 1.54, $\underline{1}$ 1.9, $\alpha +2.55^\circ \pm 0.05^\circ$).

7. Action of hydrogen bromide on the bis(D-camphor)-3,3'-mercury obtained by symmetrization of the diastereomer (III) of 3-bromomercuri-D-camphor by hydrazine hydrate. 0.45 g unrecrystallized bis(D-camphor)mercury, obtained in experiment 6 by symmetrization with hydrazine hydrate of the diastereomer (III) with $[\alpha]^{18}_D +28.7^\circ \pm 1.2^\circ$, was dissolved in 25 ml methyl alcohol. In the course of 30 min 2 ml of alcoholic hydrogen bromide (containing 0.008 g HBr) was added dropwise to the solution with vigorous stirring. The alcohol was evaporated off and the dry residue was washed with water and ether (5 ml). Yield 0.3 g (80%).

M. p. 218-220°, $[\alpha]^{18}_D +55.4^\circ \pm 1.7^\circ$ (c 1.57, $\underline{1}$ 1.9, $\alpha +1.65^\circ \pm 0.05^\circ$).

Found %: C 27.94, 27.83; H 3.52, 3.51. $C_{10}H_{15}OHgBr$. Calculated %: C 27.82; H 3.50.

8. Racemization of bis(L-camphor)-3,3'-mercury (obtained by symmetrization of the diastereomer (I) of 3-bromomercuri-L-camphor by sodium thiosulfate) by heating in aqueous dioxane. Diastereomer (I) was symmetrized by sodium thiosulfate [1]. The product was bis(L-camphor)mercury, which on treatment with hydrogen bromide gave diastereomer (I) with $[\alpha]^{18}_D -38.8^\circ \pm 1.8^\circ$. The resulting bis(camphor)mercury was dissolved in 30% aqueous dioxane and the solution was boiled 2 hr. The solvent was evaporated off and the substance was again isolated.

a) 1 g of the above-prepared bis(L-camphor)mercury was dissolved in 25 ml methyl alcohol. In the course of 30 min, 2.5 ml alcoholic hydrogen bromide (containing 0.016 g HBr) was added dropwise with vigorous stirring. The alcohol was evaporated off; the dry residue was washed with water and ether. Yield of 3-bromomercuri-L-camphor 0.6 g (72%).

M. p. 217-219° (from 60% aqueous dioxane), $[\alpha]^{18}_D -54.9^\circ \pm 1.4^\circ$ (c 1.53, $\underline{1}$ 1.9, $\alpha -1.6^\circ \pm 0.05^\circ$).

b) 2 g bis(camphor)mercury, isolated after heating in aqueous dioxane, was recrystallized from 25 ml 70% aqueous dioxane.

$[\alpha]^{18}_D -152.1^\circ \pm 1.3^\circ$ (c 1.99, $\underline{1}$ 1.9, $\alpha -5.75^\circ \pm 0.05^\circ$).

After recrystallization from 25 ml 70% aqueous dioxane, the substance had $[\alpha]^{18}_D -220^\circ \pm 2.5^\circ$ (c 1.05, $\underline{1}$ 1.9, $\alpha -4.4^\circ \pm 0.05^\circ$).

After a third recrystallization from 25 ml 70% aqueous dioxane, the substance had $[\alpha]^{18}_D -236.6^\circ \pm 2.4^\circ$ (c 1.05, $\alpha -4.85^\circ \pm 0.05^\circ$).

9. Interaction of the diastereomer (I) of 3-bromomercuri-L-camphor with a deficiency of hydrazine hydrate in dioxane. To a solution of 0.06 g hydrazine hydrate in 15 ml dioxane was added 2 g diastereomer (I) with $[\alpha]^{18}_D -30.7^\circ \pm 1.2^\circ$. After half an hour, the metallic mercury was filtered off. The filtrate was evaporated to dryness and the residue was washed with water and benzene. Yield of 3-bromomercuri-L-camphor 0.4 g.

M. p. 210-219°, $[\alpha]^{18}_D -43.5^\circ \pm 1.3^\circ$ (c 12.07, $\underline{1}$ 1.9, $\alpha -1.7^\circ \pm 0.05^\circ$). After recrystallization from aqueous dioxane the substance had m. p. 220-222°, $[\alpha]^{18}_D -38.9^\circ \pm 3.7^\circ$ (c 0.7, $\underline{1}$ 1.9, $\alpha -0.5^\circ \pm 0.05^\circ$).

Found %: C 27.93, 27.81; H 3.75, 3.56. $C_{10}H_{15}OHgBr$. Calculated %: C 27.82; H 3.50.

10. Isomerization of diastereomer (II) of 3-bromomercuri-L-camphor in dioxane in presence of hydrazine hydrate. 0.8 g diastereomer (II) with $[\alpha]^{18}_D -123.1^\circ \pm 1.8^\circ$ was added to a solution of 0.02 g hydrazine hydrate in 15 ml dioxane. After the reaction mixture had stood for half an hour, the precipitated mercury was filtered off. The filtrate was evaporated and the residue washed with water and benzene (2 mm). Yield 0.5 g.

M. p. 215-218°, $[\alpha]^{18}_D -73.1^\circ \pm 2.5^\circ$ (c 1.08, $\underline{1}$ 1.9, $\alpha -1.5^\circ \pm 0.05^\circ$).

Found %: C 27.87, 27.86; H 3.65, 3.60. $C_{10}H_{15}OHgBr$. Calculated %: C 27.82; H 3.50.

11. Preparation of 3-bromomercuri-3-benzyl-L-camphor. 4 g magnesium turnings was put into a three-necked 500-ml flask equipped with dropping funnel, reflux condenser and stirrer. 20 ml absolute ether and 0.5 ml ethylene bromide were then run in. The reaction mixture was cautiously heated until reaction started. Addition was then made of two-thirds of a solution of 50 g 3-bromo-3-benzyl-L-camphor in 300 ml absolute ether. The reaction velocity was regulated with a water bath. The remaining one-third of the ethereal solution of 3-bromo-3-benzyl-L-camphor was then added dropwise. Completion of the reaction was effected by heating for 2 hr on a water bath. Portionwise addition (in 1-2 g portions) was made of 71 g mercuric bromide (75% excess) to the Grignard reagent in the course of an hour. The mixture was thereupon heated on a water bath for 3 hr. A dark-red, viscous oil settled at the bottom of the flask when the reaction was at an end. The upper ethereal layer was poured off and the oil was treated with cold water to give a precipitate of 3-bromomercuri-3-benzyl-L-camphor. The precipitate was filtered and washed with hot water. After recrystallization from methyl alcohol the yield was 35 g (43%).

M. p. 118-119°, $[\alpha]_D^{25} + 10.6^\circ \pm 0.9^\circ$ (c 2.98, $\underline{1}$ 1.9, $\alpha + 0.60^\circ \pm 0.05^\circ$).

The angle of rotation of the product did not change after further recrystallizations from alcohol, acetone or ligroin. In all cases a substance with the same angle of rotation was isolated from the filtrate.

Found %: C 39.09, 39.20; H 4.12, 4.26. $C_{17}H_{21}OHgBr$. Calculated %: C 39.12; H 4.05.

3-Bromomercuri-3-benzyl-L-camphor is a colorless substance, easily soluble in chloroform, acetone, benzene and dioxane, less readily soluble in alcohol and ligroin. It is easily decomposed by dilute hydrochloric acid, and it slowly breaks down on standing in the air.

12. Symmetrization of 3-bromomercuri-3-benzyl-L-camphor. 4 g 3-bromo-3-benzyl-L-camphor was dissolved in 50 ml dry chloroform. A stream of dry ammonia was passed through the solution for 30 min. The resulting finely dispersed precipitate was centrifuged and filtered. The filtrate was evaporated to dryness and the residue was recrystallized from alcohol. Yield of 3,3'-mercuri-bis-3-benzyl-L-camphor 2 g (74%).

M. p. 150-153°, $[\alpha]_D^{25} - 31.7^\circ \pm 1.6^\circ$ (c 1.58, $\underline{1}$ 1.9, $\alpha - 0.95^\circ \pm 0.05^\circ$).

The specific rotation of the compound did not change after further recrystallizations.

Found %: C 59.78, 59.76; H 6.21, 6.47. $C_{34}H_{42}O_2Hg$. Calculated %: C 59.76; H 6.18.

3,3'-Mercuri-bis-3-benzyl-L-camphor is a colorless crystalline substance, readily soluble in acetone, ether, benzene and dioxane, less readily soluble in alcohol. It gradually decomposes with separation of mercury on standing.

SUMMARY

1. A study was made of the reaction of symmetrization of both of the diastereomers of 3-bromomercuri-L-camphor and of one of the diastereomers of 3-bromomercuri-D-camphor under the action of hydrazine hydrate.
2. Racemization of configuration at the α -carbon atom was established in each case. This effect may be a stereochemical consequence of the symmetrization reaction itself or it may be due to racemization of the final organomercuric compounds under the influence of a basic reagent (hydrazine hydrate).
3. It was shown that the less stable diastereomer of 3-bromomercuri-L-camphor isomerizes to the more stable diastereomer when in contact with a small quantity of hydrazine hydrate in dioxane.
4. 3-Methyl-, 3-ethyl- and 3-benzyl-3-bromomercuricamphor were prepared. Symmetrization of the last compound under the action of ammonia was studied.

LITERATURE CITED

- [1] O. A. Reutov and Lu, Ching-chu, J. Gen. Chem. 29, 182 (1959).*
- [2] O. A. Reutov and Lu Ching-chu, Proc. Acad. Sci. USSR, 110, 575 (1956).*
- [3] G. F. Wright, Canad. J. of Chem., 30, 268 (1952).

*Original Russian pagination. See C.B. Translation.

Received March 18, 1958

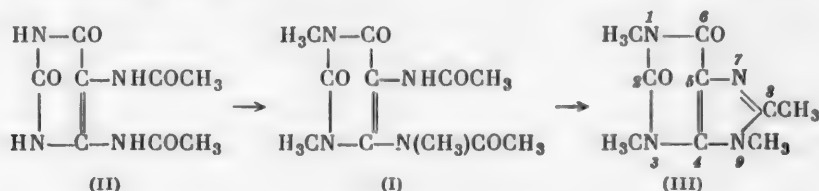
THE TRANSFORMATION OF URIC ACID INTO 8-METHYLSXANTHINE

III. SYNTHESIS OF METHYLISOCAFFEINE AND THE STRUCTURE OF THE TRIACETYL DERIVATIVES OF 4,5-DIAMINO-URACIL

E. S. Golovchinskaya

S. Ordzhonikidze ALL-Union Chemicopharmacological Scientific Research Institute

In the preceding communication [1] the cyclization of 1,3-dimethyl-4-acetylmethylamino-5-acetylaminouracil (the trimethylacetate **I**) was described. The trimethylacetate was obtained by methylation of 4,5-di(acetylamino)uracil [2] (the diacetate **II**) which is formed by short-period heating of uric acid with acetic anhydride in presence of pyridine bases.*



Cyclization of (**I**) takes place with good yield on heating with mineral acids and leads to formation of 1,3,8,9-tetramethylxanthine, i.e. methylisocaffeine (**III**).

The literature was searched for a short and simple synthesis of methylisocaffeine (**III**); the latter substance might serve as starting compound (see [4]) for a series of methylated isoxanthines whose biological properties have not previously been closely investigated. In view of their structural similarity to the purine nucleosides and lack of similarity to purine alkaloids (caffeine, theobromine, theophylline - double bond in the 7,8-position inside of the 8,9-position), isoxanthine derivatives may also differ from the above-mentioned xanthines in biological activity.

The few methods noted in the literature for preparation of methylisocaffeine and other methylated isoxanthines are based on fairly complex schemes involving many steps. The earliest synthesis of isocaffeine and methylisocaffeine [5], was based on reaction of 1,3-dimethyluracil with methyl thioisocyanate. A very similar synthesis [6] starts from 4,5-diaminouracil [6]. Xanthines substituted in the 9-position were prepared from the diamide of monomethylimidazole-4,5-dicarboxylic acid by the Hofmann reaction [7].

A shorter route - cyclization of 1,3-dimethyl-4-methylamino-5-acetylaminouracil [trimethyl-(1,3,4)-monoacetate] by the action of formamide or acetamide [8] - has not yet yielded (**III**) in sufficient quantity due to the difficulty of isolation of the original trimethyl monoacetate.

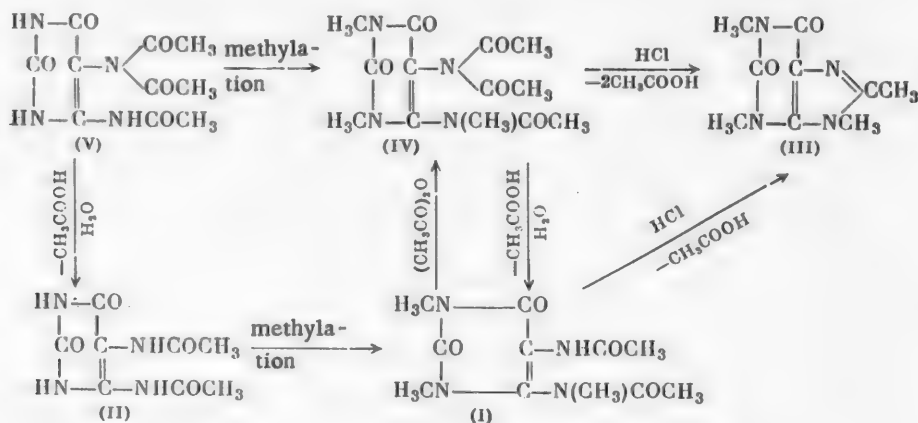
Practical application of our previously proposed method (mentioned above) of synthesis of methylisocaffeine (**III**) [1], which is relatively short, is also limited by the difficulty of extraction of the trimethyl-

*In this communication the names "triacetate, diacetate and monoacetate", proposed by Bredereck et al. [3] for acetylated derivatives of 4,5-diaminouracil, are used only for the sake of brevity. These names are not intended to characterize their structure.

acetate (I) from aqueous solution after methylation, due to its very high solubility in water. Moreover, the yield of diacetate (II) (crystallized from water) does not exceed 40-45% calculated on the uric acid. An additional 25-30% of substance, calculated on the uric acid taken, could be isolated from the aqueous mother liquors after separation of (II) and evaporation. But this product was found to be a mixture of diacetate and monoacetate. • Consequently, the total yield of methylisocaffeine (calculated on the uric acid) barely exceeded 27-28%.

A method has now been found for preparation of methylisocaffeine (III) from uric acid by the same scheme but without isolation of the intermediate products (II) and (I) in the pure state. Heating with mineral acid of the solution resulting from methylation of (II) leads to cyclization of the (I) present in this solution and to its transformation into (III). The latter is not very soluble in water (see table) and is therefore nearly quantitatively brought down from the reaction mixture on its neutralization. The most laborious operation of the whole synthesis - extraction of (I) from aqueous solution by organic solvents - is thus eliminated and with it, the otherwise inevitable losses. It is also possible to avoid the rather heavy losses of the starting diacetate (II) associated with its partial hydrolytic cleavage during crystallization from water. This can be done by methylating the whole of the unpurified product of reaction of uric acid with acetic anhydride, instead of methylating the crystalline diacetate. The first part of the synthesis is thereby greatly simplified since working-up of the cleaved substance with large volumes of water (1:30) and subsequent evaporation of the filtrates are then unnecessary. The entire synthesis is radically simplified by these modifications and the yield of methylisocaffeine is considerably increased and reaches 44-45% calculated on the uric acid.

Methylation of the unpurified cleaved substance is accompanied by deposition from the reaction solution of stout crystals with m. p. 178-180° which gradually dissolved during the further course of the reaction. These crystals are easily hydrolyzed by water with formation of (I) and with separation of 1 mole acetic acid. The crystals are converted into 1,3-dimethyl-4,5-di(acetylmethylamino)-uracil (the tetramethyldiacetate) on methylation in an aqueous alkaline medium. They remain unchanged after prolonged heating with acetic anhydride. On the other hand, boiling with dilute mineral acids converts them into methylisocaffeine (III); this reaction is accompanied by separation of 2 moles acetic acid. These observations led to the conclusion that the crystalline substance is a methylated derivative of the triacetate, i.e. one of the products of cleavage of uric acid [9] whose structure had not previously been conclusively elucidated. Its conversion into (I) and (III) indicates that it contains three methyl groups which are undoubtedly linked to the two terminal nitrogens (N)₍₁₎ and (N)₍₃₎ and with the nitrogen of the NH₂ group in the 4-position. This arrangement of the methyl groups exactly fixes the position of the 3rd acetyl group in the methylated, and consequently also in the original, triacetate; the only available site for it in the molecule is the NH₂ group in the 5-position; consequently, the structure (IV) and (V) must be assigned to the two triacetates in question.

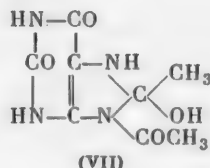
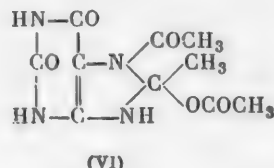


•The next communication deals with the problems associated with characterization of the monoacetate present in the mother liquors and with the investigation of the causes of its formation.

For the purpose of final confirmation of their structure, the methylated triacetate with m. p. 178-180° was shown to be identical with 1,3-dimethyl-4-acetylmethylamino-5-diacetylamino-uracil (IV) synthesized by methylation of (II) followed by acetylation of the resulting (I) [1].

The role of the triacetate in the preparation of 8-methylxanthine had remained obscure for a long time.

It was only recently concluded [3] that it is one of the original intermediate products of the reaction which is easily saponified by water with formation of the diacetate in process of crystallization. It was assigned structure (VI). A still earlier suggestion that the triacetate was an intermediate had been made by Strukov and Diskina [10]. In both cases the authors based their ideas of the structure of the triacetate on the views of Biltz and Schmidt [11] about the bicyclic structure of the diacetate (VII, and not II).



V. I. Khmelevskii and O. I. Durnitsyna [12] have again confirmed that the triacetate is indeed an intermediate in the reaction. They concluded that it is an acetylated derivative of the diacetate of the same structure as (II), which I had established for the latter [2]; on the basis of the difference in chemical properties between the two amino groups of 4,5-diaminouracil, they attributed to it the structure of (V). The very plausible assumption required convincing experimental confirmation. This is provided for the first time in the present work.

Two purposes have thus been served by the preparation of methylisocaffeine (III) directly from uric acid, i.e. without separation of the pure intermediate substances. Firstly, the synthesis has been greatly simplified and the yield increased; secondly, full proof has been obtained of the hitherto uncertain structure of the triacetate - one of the intermediate substances in the transformation of uric acid into 8-methylxanthine.

Data have incidentally been obtained concerning the desirability of the addition of glacial acetic acid during cleavage of uric acid, as proposed by V. I. Khmelevskii [13] with the objective of increasing the yield of diacetate (II). Experiments showed that the presence of acetic acid at the start of the reaction indeed has a marked influence on the outward appearance of the reaction mass (color, mobility) and on the rate of evolution of CO₂. The great mass of experimental material nevertheless shows convincingly that the final yield of methylisocaffeine (III) is quite unaffected by this addition; in parallel experiments, run in the presence and absence of acetic acid, the yield of (II) was identical.

EXPERIMENTAL

Preparation of methylisocaffeine from uric acid. a) 150 g uric acid, 600 ml acetic anhydride and 150 g pyridine bases* were stirred at the boil for 4 hr 30 min. The precipitate was filtered, washed with dichloroethane, treated 5 min with 4500 ml boiling water and filtered. The weight of the water-insoluble residue containing 40% of 8-methylxanthine was 17.35 g. The cooled filtrate deposited 80.9 g (40.1%) of diacetate (sometimes with a trace of monoacetate). Another 38.1 g of a mixture of diacetate and monoacetate came down from the mother liquor after concentration to a small volume.

Into a suspension of the 80.9 g diacetate in 300 ml water were run (simultaneously, with good stirring) 128 ml dimethyl sulfate and 88 ml 40% NaOH solution at pH 6.7-6.8 (bromothymol blue reagent). Reaction temperature 30-35°. Solution was complete at the end of the reaction. Addition was then made of 100 ml hydrochloric acid (d 1.17) and the mass was boiled 5 hr. The cooled solution was diluted with 2500 ml water and neutralized with alkali (good stirring) to pH 6.7-7.0. The precipitate (44.1 g) was filtered and crystallized from 450 ml water containing carbon. The methylisocaffeine had m. p. 258-260°; yield 39 g (52.4% on the diacetate or 21.07% on the original uric acid). 38.1 g of mixture separated on concentration of the aqueous

*The boiling point of the pyridine bases scarcely affected the results.

filtrate and was methylated under the same conditions (150 ml water, 64 ml dimethyl sulfate and 44 ml concentrated NaOH solution). The reaction solution crystallized at the end of the methylation. After filtration (weight of crystallizing substance 12.6 g, m. p. 276-279°), the solution was boiled 5 hr with 50 ml hydrochloric acid, then diluted with 500 ml water, and neutralized. 15.5 g of (III) came out and was crystallized from 150 ml water (containing carbon). M. p. 258-260°, weight 13.2 g (7.1% calculated on the uric acid). Total yield of methylisocaffeine 52.5 g (28.07%).

b) The mixture of solids which had been washed with dichloroethane (experiment a) was boiled with 4500 ml water; the filtrate (without isolation of the diacetate) was concentrated in vacuum to a volume of 500 ml, the whole of the crystallizing mass was methylated (192 ml dimethyl sulfate, 132 ml concentrated alkali solution). The solid (23 g, m. p. 274-276°) was filtered; the solution was boiled with 150 ml hydrochloric acid and then diluted with 3500 ml water. Yield of crystallizing (III) 52.6 g (28.4% calculated on the uric acid), m. p. 258-260°.

c) Reactants were 200 g uric acid, 800 ml acetic anhydride and 200 ml pyridine bases; the mixture was boiled 5 hr. Weight of precipitate 227.3 g. The latter was methylated without prior treatment with water (376 ml dimethyl sulfate, 266 ml concentrated NaOH, 600 ml water, pH 6.2-6.7, 35°). The crystalline product was filtered off and recrystallized from 400 ml alcohol. Weight of crystals 21.7 g * which after a second recrystallization from alcohol (1 : 10) or from water (1 : 6) melted at 178-180°.

Found %: C 50.53; H 5.82; N 17.95. $C_{13}H_{18}O_5N_4$. Calculated %: C 50.32; H 5.80; N 18.06.

Boiling of the aqueous filtrate with 200 ml hydrochloric acid (d 1.19) gave 99.2 g (40.1%) of crystalline (III) with m. p. 258-259°.

10.85 g of the crystals with m. p. 176-179° (i.e. one half of the yield from the experiment), 100 ml water and 20 ml hydrochloric acid (d 1.19) were boiled 4 hr. On neutralization of the solution deposited a compound with m. p. 256-258°; mixed melting test with (III); 256-258°; yield 6.7 g (5.4% calculated on the uric acid).

Solubility of Methylisocaffeine in Water **

Temperature	Content of (III) (in wt. %)
15°	0.15
19	0.18
24	0.24
31	0.35
41	0.51
53	0.95
56	1.18
63	1.67
77	3.22
90	6.69

Found %: N 26.97. $C_9H_{12}O_2N_4$. Calculated %: N 26.92.

Examination of the crystals with m. p. 178-180°. a) Heating with acetic anhydride. 1 g of the substance was boiled with 10 ml acetic anhydride in vacuo. The residue was washed with ether; the starting substance was obtained; m. p. 178-180°, weight 0.98 g.

b) Methylation. Into 5 g of the substance in 30 ml water were simultaneously run (at 30-35°) 5 ml dimethyl sulfate and 3.5 mg concentrated NaOH solution. Addition of each drop of alkali brought about a pronounced alkaline reaction (pH 9) which disappeared after a short time. The duration of methylation was 2 hr and the final pH of the solution was 6. The reaction mass was heated at 80° and then cooled; the greater part of the water was taken off in vacuo. The residual syrup crystallized on treatment with alcohol and the crystals were extracted with boiling chloroform. The chloroform was distilled off and the residue (2.2 g) was crystallized from alcohol; m. p. 223-224°. A mixture with 1,3-dimethyl-4,5-di(acetylmethylamino)-uracil had m. p. 223-224° [2].

Found %: N 19.68. $C_{12}H_{18}O_4N_4$. Calculated %: N 19.82.

c) Hydrolysis (determination of acetyl groups). 1. 0.1396 g substance in 40 ml water was boiled and the evolved acetic acid was simultaneously distilled with steam into a receiver containing 0.1 N NaOH. Consumption of NaOH (titration with phenolphthalein) 4.44 ml (98.7%). Calculated 4.49 ml. The aqueous solution

* The smaller amounts of dimethyl sulfate and alkali led to a higher yield of these crystals.

** Solubilities were determined by F. E. Rabinovich in the physical chemistry laboratory.

remaining in the reaction flask was evaporated to dryness in vacuum. Dry benzene was added to the residue and distilled off, this operation being repeated many times until the distillate was dry. The so-dried residue melted at 186-189°. A mixture with 1,3-dimethyl-4-acetylmethylamino-5-acetylaminouracil [2] melted at 187-191°; a mixture with the starting substance melted at 157-167°.

Found %: N 20.67. $C_{11}H_{16}O_4N_4$. Calculated %: N 20.89.

2. A mixture of 0.1682 g substance, 20 ml 20% H_2SO_4 and 20 ml water was boiled. Consumption of 0.1 N NaOH solution 10.7 ml (197.2%). The solution was neutralized with 20% NaOH and extracted with chloroform. The solvent was driven off and the residue crystallized from water; m. p. 257-259°; the mixture with (III) had m. p. 257-259°.

d) Establishment of identity with 1,3-dimethyl-4-acetylmethylamino-5-diacetylaminouracil. 1 g 1,3-dimethyl-4-acetylmethylamino-5-acetylaminouracil, prepared by methylation of diacetate (II) [2], and 20 ml acetic anhydride were boiled 10 hr. Complete solution occurred. The acetic anhydride was taken off in vacuum, and the residue was treated with dry ether and suction-filtered. Weight 1.16 g, m. p. 175°; after recrystallization from 20 ml dry benzene, m. p. 179-181°. A mixture with the substance under investigation had m. p. 178-181°.

SUMMARY

1. A short, simple, high-yielding synthesis of 1,3,8,9-tetramethylxanthine (methylisocaffeine) from uric acid was discovered which eliminated the necessity for isolation of the intermediate products in the pure state.

2. It was found that one of the compounds formed in the process of methylation of the mixture of products of cleavage of uric acid with acetic anhydride is 1,3-dimethyl-4-acetylmethylamino-5-diacetylaminouracil. The structure of this compound was established by its chemical transformations and also by its identity with a specimen synthesized by acetylation of 1,3-dimethyl-4-acetylmethylamino-5-acetylaminouracil.

3. Formation of 1,3-dimethyl-4-acetylmethylamino-5-diacetylaminouracil on methylation of the mixture of products of cleavage of uric acid is proof that the original triacetyl derivative of 4,5-diaminouracil present in this mixture is 4-acetylaminouracil.

LITERATURE CITED

- [1] E. S. Golovchinskaya, J. Gen. Chem. 24, 146 (1954).*
- [2] E. S. Golovchinskaya, J. Gen. Chem. 24, 136 (1954).*
- [3] H. Brederick, J. Hennig, and W. Pfeleiderer, Ber., 86, 321 (1953).
- [4] E. S. Golovchinskaya, J. Gen. Chem. 18, 2129 (1948); J. Gen. Chem., Supp. Vol. I, 692, 702 (1953); E. S. Golovchinskaya and E. S. Chaman, J. Gen. Chem., 22, 528, 535, 2220, 2225 (1952).*
- [5] H. Biltz, and K. Strufe, Lieb. Ann, 423, 220 (1921).
- [6] F. F. Blicke and R. L. Schaaf, J. Am. Chem. Soc. 78, 5857 (1956).
- [7] R. A. Baxter and F. S. Spring, J. Chem. Soc., 1945, 232; 1947, 378; 1948, 523.
- [8] H. Brederick, J. Hennig, W. Pfeleiderer, and G. Weber, Chem. Ber., 86, 333 (1953).
- [9] German Patent 126797; Frdl., 6, 1185.
- [10] I. T. Strukov and L. S. Diskina, Farmatsiya, 6, 16 (1945).
- [11] H. Biltz, and W. Schmidt, Lieb. Ann. 431, 71 (1923).
- [12] V. I. Khmelevskii and O. I. Durnitsyna, J. Gen. Chem., 26, 755 (1956).*
- [13] V. I. Khmelevskii, Author's Certificate No. 102848.

* Original Russian pagination. See C.B. Translation

Received March 21, 1958.

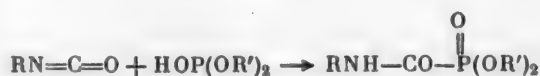
A NEW METHOD OF SYNTHESIS OF ESTERS OF PHOSPHONIC AND THIOPHOSPHONIC ACIDS

XXX. THE REACTION OF DIALKYLPHOSPHOROUS AND DIALKYLTHIOPHOSPHOROUS ACIDS WITH KETENE

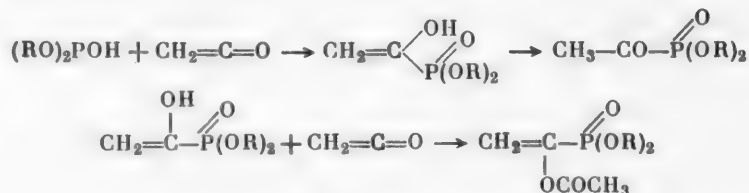
V. I. Nikitina and A. N. Pudovik

Kazan State University

In the preceding investigations we showed that partial esters of phosphorus acids (dialkylphosphorous and dialkylthiophosphorous acids) and acid esters of alkyl- and arylphosphonic acids in presence of catalysts easily combine at the carbon-carbon double bond with unsaturated ketones, esters of unsaturated ketones, esters of unsaturated phosphonic acids, esters of vinylic alcohols, etc. [1]. Partial esters of phosphorus acids are also capable of combining at the nitrogen-carbon double bond in anils to form aminophosphonic esters [2], as well as at the carbonyl group in aldehydes and ketones to form hydroxyphosphonic esters [3]. In the case of unsaturated aldehydes, addition also first occurs at the carbonyl group, but in the further course of the reaction the double bond is involved [4]. One of us and Kuznetsova showed that dialkylphosphorous and dialkylthiophosphorous acids are capable of adding on to esters of isocyanic acid [5].



In continuation of these investigations and with the objective of widening their scope, we decided to carry out the addition of dialkylphosphorous and dialkylthiophosphorous acids to ketene. Ketene and its homologs are known to be extraordinarily reactive substances. Dialkylphosphorous acids did not react with ketene in the absence of a catalyst. Reaction could only be effected in presence of a small quantity of pyridine or sulfuric acid. Two products were formed in each case when ketene was reacted with dimethyl-, diethyl-, di-*n*-butyl- and diisobutylphosphorous acids, namely, dialkyl esters of acetophosphonic acid and products of their further reaction with ketene:

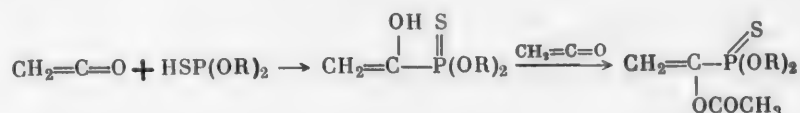


The total yield of both products was usually 75-80%; the proportion of acetoxyvinylphosphonic esters is several times higher than that of acetophosphonic esters. The esters of acetophosphonic acids were identified by their constants, which were identical with those of previously described products [6].

The double bond was determined in the acetoxyvinylphosphonic acids with the objective of confirming

their structure. Bromination of these compounds by the McIlhiney method goes slowly and incompletely. A value of 60-70% of the theoretical is found for the double bond when the analysis is performed by the standard procedure. Ozonization of the acetate of the dimethyl ester of hydroxyvinylphosphonic acid gave formaldehyde, which was identified in the form of its condensation products with dimedone and β -naphthol. The second step of the reaction was performed separately. Reaction of the ethyl ester of acetophosphonic acid with ketene in presence of pyridine gave the diethyl ester of acetoxyvinylphosphonic acid. Taken in conjunction with the analytical results and data for molecular refraction, the results confirm the structure of the acetates of hydroxyvinylphosphonic esters. The constants of the acetophosphonic esters and of the acetoxyvinylphosphonic esters are presented in the table (compounds 1-8).

A similar course is followed by the reaction of ketene with dialkylthiophosphorous acids. In these reactions, however, the yields of acetoxyvinylthiophosphonic esters are lower than in the reactions with dialkylphosphorous acids. They amount to 40-60%. Acetothiothiophosphonic esters could not be isolated, probably due to the small quantities of reactants entering into reaction. The constants of the prepared acetoxyvinylthiophosphonic acids are set forth in the table (compounds 9-11). The reactions go according to the equation:



After the investigation had been completed, the results obtained by Kennedy and Meaburn [7] came to our knowledge. These authors likewise studied the reaction of some dialkylphosphorous acids with ketene. Judging by the short abstract of the paper, they obtained solely high-boiling products of reaction of ketene with diethyl-, dipropyl- and diisopropylphosphorous acids. The reactions were carried out in presence of boron fluoride and sulfuric acid. Acetophosphonic esters were apparently not isolated by these authors.

EXPERIMENTAL

Procedure for addition of dialkylphosphorous and dialkylthiophosphorous acids to ketene. Ketene was prepared with the aid of a ketene lamp in a yield of 0.05 mole per hour. After passing through water condensers, the ketene entered the reaction flask, which was equipped with a condenser and a thermometer. The best results were obtained by reaction at 35-40° with ethyl ether or carbon tetrachloride as solvent, and with pyridine or sulfuric acid (1% on the weight of reaction mixture) as catalyst. The color of the reaction mixture changed to dark brown when ketene was passed through.

Reaction was performed with 25-30 g dialkylphosphorous acids or 5-10 g dialkylthiophosphorous acids, 50-75 ml carbon tetrachloride or diethyl ether, and several drops of pyridine or sulfuric acid. An excess of ketene was introduced. Solvent was eliminated from the reaction mixture by distillation in vacuo, and the residue was distilled from an Arbuzov flask. The products were then redistilled several times through short columns. Constants of the products, data for phosphorus determinations, molar refractions and yields are set forth in the table.

Ozonization of the dimethyl ester of 1-acetoxyvinylphosphonic acid. Ozonized oxygen was passed for 15 hr through a solution of 3 g dimethyl ester of 1-acetoxyvinylphosphonic acid in 20 ml carbon tetrachloride which was cooled with iced water. After the carbon tetrachloride had been taken off in vacuo, ether was poured over the ozonide, which was then stood for 24 hr. The ozonide was decomposed by heating with 50 ml water on a water bath. Formaldehyde was detected in the first 20 ml of distillate by the following reactions: 1) β -naphthol gave pink crystals with m. p. 189° (m. p. in mixed melting test 188-189°); 2) dimedone gave colorless needles with m. p. 188° (m. p. in mixed melting test 189°).

Reaction of diethyl ester of acetophosphonic acid with ketene. 2 drops of pyridine were added to a solution of 10 g diethyl ester of acetophosphonic acid in 50 ml carbon tetrachloride, and an excess of ketene was passed through. The temperature of the reaction mixture was held at about 35-40°. The color of the reaction mixture changed from colorless to dark brown. The carbon tetrachloride was removed in vacuo and the residue was distilled from an Arbuzov flask to give the following fractions: 1st, to 104° (14.5 mm), n_D^{20} 1.4270; 2nd, 105-140° (16 mm), n_D^{20} 1.4210; 3rd, 140-146° (16 mm), n_D^{20} 1.4380.

Constants of Acetophosphonic Esters and Acetoxyvinylphosphonic Esters

Compound No.	Formula	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	$M R_D$		% P		Yield(in %)
					found	calc.	found	calc.	
1	$\text{CH}_3\text{—CO—P}(=\text{O})(\text{OCH}_3)_2$	93–95°(16)	1.4200	1.2102	—	—	—	—	5
2	$\text{CH}_2=\text{C}(\text{OCOCH}_3)\text{—P}(=\text{O})(\text{OCH}_3)_2$	129.5–130(11)	1.4390	1.2170	41.94	41.86	15.68	15.97	68
3	$\text{CH}_3\text{—CO—P}(=\text{O})(\text{OC}_2\text{H}_5)_2$	103–105 (13)	1.4209	1.1005	—	—	—	—	5.6
4	$\text{CH}_2=\text{C}(\text{OCOCH}_3)\text{—P}(=\text{O})(\text{OC}_2\text{H}_5)_2$	135–135.5(13)	1.4375	1.1347	51.31	51.19	13.77	13.96	71
5	$\text{CH}_3\text{—CO—P}(=\text{O})(\text{OC}_4\text{H}_9)_2$	128–130 (13)	1.4300	1.0190	—	—	—	—	2.5
6	$\text{CH}_2=\text{C}(\text{OCOCH}_3)\text{—P}(=\text{O})(\text{OC}_4\text{H}_9)_2$	161–162 (10)	1.4420	1.0613	69.54	69.67	10.75	11.15	80
7	$\text{CH}_3\text{—CO—P}(=\text{O})(\text{iso-OC}_4\text{H}_9)_2$	119–120 (14)	1.4280	1.0015	—	—	—	—	3
8	$\text{CH}_2=\text{C}(\text{OCOCH}_3)\text{—P}(=\text{O})(\text{iso-OC}_4\text{H}_9)_2$	152–153 (12)	1.4362	1.0373	70.12	69.67	10.68	11.15	75
9	$\text{CH}_2=\text{C}(\text{OCOCH}_3)\text{—P}(=\text{S})(\text{OC}_2\text{H}_5)_2$	121–122 (13)	1.4825	1.2104	49.50	49.45	14.58	14.76	40
10	$\text{CH}_2=\text{C}(\text{OCOCH}_3)\text{—P}(=\text{S})(\text{OC}_2\text{H}_5)_2$	126–128 (11)	1.4680	1.1266	58.73	58.69	13.41	13.02	42
11	$\text{CH}_2=\text{C}(\text{OCOCH}_3)\text{—P}(=\text{S})(\text{iso-OC}_4\text{H}_9)_2$	153–154 (11)	1.4590	1.0409	77.22	77.16	10.13	10.54	58

Redistillation of the 3rd fraction yielded 1.2 g diethyl ester of acetoxyvinylphosphonic acid; b. p. 135-136.5°, n_D^{20} 1.4370, d_4^{20} 1.1316.

SUMMARY

1. A study was made of the addition to ketene of dimethylphosphorous, diethylphosphorous, dibutylphosphorous, diisobutylphosphorous, dimethylthiophosphorous, diethylthiophosphorous and diisobutylthiophosphorous acids.
2. The reactions go in two steps. The initially formed acetophosphonic or acetothiophosphonic esters react further with ketene to give dialkyl esters of acetoxyvinylphosphonic and acetoxyvinylthiophosphonic acids, respectively.

LITERATURE CITED

- [1] A. N. Pudovik, *Prog. Chem.* 22, 547 (1954).
- [2] A. N. Pudovik, *Proc. Acad. Sci. USSR*, 92, 773 (1953).
- [3] V. S. Abramov, *J. Gen. Chem.* 22, 647 (1952); * 23, 257, 1013 (1953).
- [4] A. N. Pudovik and Yu. P. Kitaev, *J. Gen. Chem.* 22, 467 (1952).
- [5] A. N. Pudovik and A. V. Kuznetsova, *J. Gen. Chem.* 25, 1369 (1955).
- [6] M. I. Kabachnik and P. Rossiiskaya, *Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1945, 365.
- [7] J. Kennedy and Meaburn, *Ch. A.* 4933^e (1957).

Received February 28, 1958

* Original Russian pagination. See C.B. Translation.

THE REACTION OF DIALKYLPHOSPHOROUS ACIDS WITH ALDEHYDES AND KETONES

XIX. DI-1-TRICHLOROMETHYLCYCLOPENTYL-1 ESTERS OF α -HYDROXY-ALKYLPHOSPHONIC ACID

V. S. Abramov and V. K. Khafrullin

Kazan Institute of Chemical Technology

Reactions of condensation of dialkylphosphorous acids with carbonyl compounds are being studied to an ever increasing extent. It was found that partial esters of aryl(alkyl)phosphorous acids readily condense with aldehydes and ketones [1]; dialkylphosphorous acids similarly react with aldehydes and ketones [2]. Dialkylphosphorous acids condense not only with the carbonyl, but also with the $>C=S$ group, for example, with thiourea [3]. Preliminary results have been obtained for reactions of dialkylphosphorous acids with thioketones and thioaldehydes.

We have investigated condensation of chloro-substituted dialkylphosphorous acids with aldehydes and ketones [4], and in still earlier work we had established that these reactions go easily in the absence of basic catalysts at room temperature.

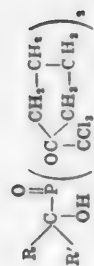
Further work along these lines is presented in this communication. Reaction of tertiary chlorosubstituted alcohols with phosphorus trichloride gives the acid dichlorides and acid monochlorides of the corresponding alkyl- and dialkylphosphorous acids. Acid chlorides of this type were also obtained from 1-trichloromethylcyclopentan-1-ol [5]. Water transforms the monoacid chlorides into the corresponding dialkylphosphorous acids. We characterized di-1-trichloromethylcyclopentyl-1-phosphorous acid as a viscous, poorly mobile, undistillable liquid:

n_D^{20} 1.5235, d_4^{20} 1.4770, M_R 93.76. $C_{12}H_{17}O_2Cl_3P$. Calculated: 93.29 [5].

The acid crystallized on keeping and had m. p. 37-38°. It condenses with aldehydes and ketones in the absence of a catalyst when the reactants are mixed. The reaction is completed at room temperature after 21-50 hr. Gentle heating (40-60°) speeds up the reaction. The reaction is usually assumed to be at an end when a dense crystalline mass has been formed; however, the products of condensation with propionaldehyde, butyraldehyde and isovaleraldehyde did not crystallize completely and were therefore kept for a considerable time. We assume that the reaction takes place with the trivalent form of the phosphorous acid, just as in other reactions of chloro-substituted phosphorous acids. Products of condensation of the acid with aldehydes and ketones were prepared: di-1-trichloromethylcyclopentyl-1 esters of substituted α -hydroxymethylphosphonic acids whose constants and analyses are set forth in the table. Some of the esters were handed over for insecticidal tests.

EXPERIMENTAL

Condensations of di-1-trichloromethylcyclopentyl-1-phosphorous acid with aldehydes and ketones were performed in sealed ampoules containing 4.5 g acid and an equimolar quantity of the carbonyl compound. The ampoules were kept at room temperature. Within a few hours after the reactants had been mixed, crystals



Di-1-trichloromethylcyclopentyl-1 Esters of Substituted α -Hydroxymethylphosphonic Acids

Pre- para- tion No.	R	R'	Period (in hours)		Solvent for crystallization of the ester	Melting point	Yield (in %)	Chlorine (in %)		Phosphorus (in %)	
			of reac- tion on comple- tion	until ap- pearance of first crystals of ester				found	calc.	found	calc.
1	H	CH ₃	60	16	Acetone	143—145°	82.5	42.86	42.80	6.19	6.23
2	H	C ₂ H ₅	—	12	Acetone + water 3:1	156.5—157.5	74.5	41.40	41.63	5.98	6.06
3	H	n-C ₃ H ₇	—	15	Acetone + water 4:1	136—137	74.0	40.39	40.52	5.94	5.90
4	H	iso-C ₄ H ₉	—	16	Acetone	155—157	55.6	39.49	39.46	5.79	5.75
5	H	CCl ₃	21	4	Acetone + water 3:2	163—164	82.0	53.01	53.15	5.05	5.16
6	H	C ₆ H ₅	32	10.6	96% alcohol	143—144	92.0	38.01	38.05	5.38	5.54
7	H	p-CH ₃ C ₆ H ₄	21	9	96% alcohol	162	91.3	37.07	37.11	5.37	5.40
8	H	m-NO ₂ C ₆ H ₄	48	14	80% alcohol	156—157	77.0	35.19	35.22	5.03	5.10
9	H	o-HOC ₆ H ₄	—	—	96% alcohol	149—150	90.0	36.00	35.99	5.26	5.24
10	—	—(CH ₂) ₅ —	36	8	96% alcohol	179—180	92.0	38.40	38.51	5.30	5.46

of esters of α -hydroxyalkylphosphonic acids usually appeared, and after a short time the reaction mixture was converted into a dense, crystalline mass. At this stage the reaction was considered at an end. The esters were recrystallized from acetone, aqueous acetone or alcohol.

In some cases, for example, in condensation of the acid with propionaldehyde, butyraldehyde and isovaleraldehyde, the reaction products were not converted into a dense crystalline mass in course of time. A small quantity of viscous liquid remains in the ampoule. In such cases the crystalline portions of the products is filtered off from the liquid and then recrystallized from the solvents mentioned above. When the acid was condensed with salicylaldehyde, the mixture turned green. In course of time this color changed further to blue. After a few days the reaction mixture darkened and changed into a homogeneous immobile mass. When the latter was dissolved in alcohol, the solution deposited white crystals which were recrystallized from alcohol.

The prepared esters of α -hydroxymethylphosphonic acids consist of white, well-formed crystals. They are insoluble in water but readily soluble in common organic solvents. Reaction period, physical constants of the prepared esters and analytical data are set forth in the table.

SUMMARY

1. Di-1-trichloromethylcyclopentyl-1-phosphorous acid reacts with aldehydes and ketones in the absence of a catalyst at room temperature and gives 1-trichloromethylcyclopentyl-1 esters of substituted α -hydroxymethylphosphonic acids.
2. Ten new esters were synthesized.

LITERATURE CITED

- [1] V. S. Abramov and M. L. Kashirskii, J. Gen. Chem. 28, 3059 (1958).*
- [2] W. F. Barthel, B. H. Alexander, P. A. Giang, and S. A. Hall, J. Am. Chem. Soc. 77, 2424 (1955).
- [3] V. S. Abramov, Proc. Acad. Sci. USSR, 117, 811 (1957).*
- [4] V. S. Abramov and V. K. Khairullin, J. Gen. Chem., 26, 811 (1956);* 27, 2387 (1957);* Trans. Kazan Chem.-Tech. Inst., 23, 102 (1957).
- [5] V. S. Abramov and V. K. Khairullin, Trans. Kazan Chem.-Tech. Inst., 23, 65 (1957).

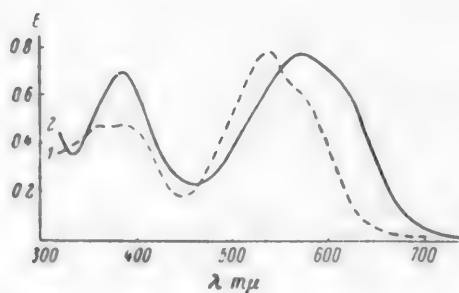
Received March 25, 1958

*Original Russian pagination. See C.B. Translation.

2-nitro-1-anthrol-4-sulfonic acid, is perfectly stable in an alkaline medium, does not react in aqueous solution with aromatic amines, and is transformed in dilute nitric acid into 2,4-dinitro-1-anthrol. 1-Nitroso-2-anthrol-4-sulfonic acid (I), like 1,2-anthraquinone-4-sulfonic acid, loses the sulfo group on treatment with caustic alkalis or aromatic amines. It is converted in this way into 1-nitroso-2,4-dihydroxyanthracene or 4-arylamino-1-nitroso-2-anthrol, respectively. These properties of nitrosoanthrolsulfonic acids are similar to the properties of the corresponding compounds of the naphthalene series. The causes of the greater lability of the sulfo group in 1-nitroso-2-hydroxy-4-sulfonic acids of naphthalene and anthracene in comparison with the sulfo group in the 2-nitroso-1-hydroxy-4-sulfonic acids must be the object of further investigation.

EXPERIMENTAL

2-Nitroso-1-anthrol-4-sulfonic acid (I). a) A mixture of 3.63 g of the sodium salt of the bisulfite compound of 1-nitroso-2-anthrol [2], 0.8 g hydroxylamine hydrochloride, 40 ml water and 0.5 ml concentrated hydrochloric acid was heated 5 hr at 80°; addition was then made of 10 g sodium chloride. After cooling, the precipitate was filtered, washed with alcohol and treated with 200 ml boiling water. The insoluble brown residue (0.4 g) was separated; crystals of sodium salt of (I) came down on cooling, and were filtered and washed with alcohol; yield 2.06 g.



Ultraviolet absorption spectra (in water). 1) 2-(2',4'-dihydroxybenzeneazo)-1-anthrol-4-sulfonic acid (III); 2) 1-(2',4'-dihydroxybenzene azo)-2-anthrol-4-sulfonic acid (IV).

The sodium salt of (I) forms small, orange needles (from water), poorly soluble in alcohol. It gives an intense green coloration with ferrous sulfate solution; it loses its water of crystallization at above 100° and turns purple-red.

Found %: H₂O 10.06; C 46.71; H 3.23; N 3.81; Na 6.37. C₁₄H₉O₅NSNa · 2H₂O. Calculated %: H₂O 9.97; C 46.54; H 3.35; N 3.88; Na 6.36.

b) A solution of 3.96 g sodium salt of the bisulfite compound of 1,2-anthraquinonedioxime [2] in 40 ml water was acidified with 1 ml concentrated hydrochloric acid and heated 5 hr at 80°. The reaction mass was treated as in a). Yield of sodium salt of (I) 1.50 g.

c) A mixture of 1.13 g sodium salt of 1,2-anthraquinonedioxime-4-sulfonic acid [3], 0.8 ml concentrated hydrochloric acid and 25 ml water was boiled 6 hr. To the dark-red solution was added 5 g sodium chloride; after cooling, the precipitate was filtered, washed with alcohol and treated with 50 ml boiling water. The solution was separated from the water-insoluble brown substance (0.09 g) and cooled. The sodium salt of (I) came down and was filtered off; yield 0.68 g.

d) To a solution of 0.63 g ammonium salt of 1,2-anthraquinone-4-sulfonic acid (obtained as described in [4]) in 15 ml water at 60° was added a solution of 0.25 g hydroxylamine hydrochloride. Orange needles began to come down almost at once. After 40-minutes' heating at 60-80°, the mixture was cooled, and the precipitate was filtered off, recrystallized from water and washed with alcohol. Yield of ammonium salt of (I) 0.48 g.

Under similar conditions, but in presence of 0.6 g crystalline sodium acetate, (I) was formed together with 0.11 g (23%) of a water-insoluble substance; the latter was sulfur-free, and a nitrogen determination indicated that it was 4-hydroxylamino-1,2-anthraquinone. Yellow prisms (from alcohol), decomposing at above 215-220° with evolution of brown fumes.

Found %: N 5.72. C₁₄H₉O₃N. Calculated %: N 5.86.

The ammonium salt of (I) crystallizes (from water) as small orange needles, poorly soluble in alcohol; boiling with sodium hydroxide converts it quantitatively into the sodium salt. Heating at above 100° causes it to lose its water of crystallization and to become greyish-brown, but the original color is restored on exposure to the air.

Found %: H_2O 5.53; N 8.04. $\text{C}_{14}\text{H}_{12}\text{O}_5\text{N}_2\text{S} \cdot \text{H}_2\text{O}$. Calculated %: H_2O 5.32; N 8.28.

2,4-Dinitro-1-anthrol. a) 1 ml 56% nitric acid was run into a solution of 1 g sodium salt of 2-nitro-1-anthrol-4-sulfonic acid in 40 ml water at 8° . A precipitate immediately started to appear and the suspension darkened and later turned orange. After 5-minutes' boiling followed by cooling, the precipitate was filtered and washed with water; yield 0.65 g. Recrystallization from acetic acid and aqueous alcohol gave orange needles with m. p. 184° (decomp.). Very poorly soluble in water, poorly soluble in alcohol and benzene, more soluble in chlorobenzene and glacial acetic acid.

b) 3 ml 56% nitric acid was run into a hot solution of 1 g sodium salt of (I) in 100 ml water, and the mixture was boiled 5 min. Yield of 2,4-dinitro-1-anthrol 0.59 g (75%), m. p. 185° (decomp.); the mixture with the compound obtained by method a) melted at 184° (decomp.).

Found %: N 9.89. $\text{C}_{14}\text{H}_8\text{O}_5\text{N}_2$. Calculated %: N 9.86.

2-Amino-1-anthrol-4-sulfonic acid. a) A solution of 12 g stannous chloride in 15 ml concentrated hydrochloric acid was run into a suspension of 3.77 g sodium salt of 2-nitro-1-anthrol-4-sulfonic acid in 70 ml water at 90° . The mixture was heated 20 min at $90-95^\circ$ until the original dark-red color had changed to greyish-yellow. After cooling, the precipitate was filtered, washed with water and alcohol, and reprecipitated from sodium sulfite solution; yield 2.34 g (81%). Yellow, coalescent druses of needles, darkening in the air.

b) 3.61 g sodium salt of (I) was reduced with stannous chloride as in a). Yield of 2-amino-1-anthrol-4-sulfonic acid 2.6 g (90%).

Found %: N 4.75; S 11.11. $\text{C}_{14}\text{H}_{11}\text{O}_4\text{NS}$. Calculated %: N 4.84; S 11.08.

1-Diazo-2-anthrol-4-sulfonic acid and 2-diazo-1-anthrol-4-sulfonic acid. 0.4 ml 10% ferrous sulfate solution and 20 ml 0.5 N sodium nitrite solution were run into a suspension of 3 g aminoanthrolsulfonic acid in 100 ml water. After stirring for 1 hr and clarifying with carbon at $30-40^\circ$, the brownish-red solution was treated with sodium chloride. The sodium salt of diazoanthrolsulfonic acid came down in the form of small, yellow needles which were easily soluble in water and poorly soluble in alcohol. Yield of 1-diazo-2-anthrol-4-sulfonic acid 2.85 g, and of 2-diazo-1-anthrol-4-sulfonic acid 2.2 g. The latter is less soluble in water.

Azo dyes from diazoanthrolsulfonic acids and resorcinol (III) and (IV). A mixture of 0.5 g sodium salt of diazoanthrolsulfonic acid, 0.2 g resorcinol, 20 ml water and 5 ml 10% sodium carbonate solution was stirred 1 hr at $40-50^\circ$, 10 ml concentrated hydrochloric acid was run into the deeply colored suspension, the precipitate was filtered, washed with 5% hydrochloric acid, dissolved in hot water and again brought down with hydrochloric acid; yield 0.45-0.5 g. Azo compound (IV) is readily soluble in water giving blue coloration; the less soluble (III) gives reddish-violet solutions. The dyes are quickly decomposed when alkalis are added. The absorption spectra are presented in the diagram. Measurements were made with the SF-4 spectrophotometer at 10 μ intervals.

2-Anthrol-4-sulfonic acid. 10 ml 40% sodium hydroxide was added dropwise to a solution of 2.2 g stannous chloride in 10 ml water and 0.5 ml concentrated hydrochloric acid at $5-10^\circ$. Into the resulting colorless solution of sodium stannite was introduced 2 g sodium salt of 1-diazo-2-anthrol-4-sulfonic acid at 0° . The mixture was stirred 2-3 hr until nitrogen ceased to come off; it was then heated to 50° , acidified with hydrochloric acid until weakly acidic, and filtered at 80° . The precipitated tin oxide was washed with hot water. To the filtrate was added 6 g sodium chloride; after cooling, the sodium salt of 2-anthrol-4-sulfonic acid was filtered, washed with 10% sodium chloride solution and dried; yield 1.51 g. Long, light-yellow needles (from water), very easily soluble in water, easily soluble in alcohol. The compound rapidly couples with diazo compounds; it forms a claret-colored dye with diazobenzene.

Found %: H_2O 19.72; C 45.80; H 4.82; Na 6.31. $\text{C}_{14}\text{H}_9\text{O}_4\text{SNa} \cdot 4 \text{H}_2\text{O}$. Calculated %: H_2O 19.56; C 45.64; H 4.65; Na 6.24.

1-Nitroso-2-anthrol-4-sulfonic acid (II). 15 ml 0.5 N sodium nitrite solution was run into a suspension of 2.58 g sodium salt of 2-anthrol-4-sulfonic acid in 15 ml water; this was followed by dropwise addition at below 0° of 5 ml 20% acetic acid. A viscous, brownish-red mass quickly appeared. After it had been stirred 2 hr, the precipitate was filtered, washed with 10% sodium chloride solution and with alcohol, and crystallized

from 30 ml water. Yield of sodium salt of (I) 2.08 g (84%). Nitrosation in presence of hydrochloric acid reduced the yield to 25-30% due to formation of highly water-soluble brownish-red secondary products. Small orange needles (from water), giving a deep brownish-green coloration with ferrous sulfate solution, and losing their water of crystallization and turning brown at 110°.

Found %: H_2O 7.80; C 47.67; H 3.16; N 3.97; Na 6.61. $C_{14}H_9O_5NSNa \cdot 1.5 H_2O$. Calculated %: H_2O 7.67; C 47.73; H 3.15; N 3.98; Na 6.53.

2,4-Dihydroxy-1-nitrosoanthracene. A solution of 0.4 g sodium salt of (II) in 25 ml sodium hydroxide was heated 40 min on a water bath. The color of the solution changed from reddish-brown to orange. On cooling, the solution was filtered and acidified with hydrochloric acid. Sulfur dioxide came off and an amorphous, orange precipitate came down; the latter was filtered, washed with water, dissolved in alcohol, and precipitated by addition of water; yield 0.196 g (72%). Light-yellow needles, soluble in caustic alkalies, alcohol, and glacial acetic acid, poorly soluble in water. On heating in a capillary the compound gradually decomposes at above 215°.

Found %: C 70.33; H 4.03; N 5.66. $C_{14}H_9O_3N$. Calculated %: C 70.28; H 3.79; N 5.86.

4-Phenylamino-1-nitroso-2-anthrol. 5 ml 3% aqueous solution of aniline was added to a solution of 0.3 g sodium salt of (II) in 10 ml water. A gel-like precipitate appeared and formed into yellow clots on heating. The compound was filtered, washed with water, and dried; yield 0.234 g (84%). Orange plates (from aqueous alcohol), m. p. 234° (decomp.).

Found %: N 8.83. $C_{23}H_{14}O_2N_2$. Calculated %: N 8.91.

4-(p-Tolylamino)-1-nitroso-2-anthrol. This was prepared by heating a mixture of a solution of 0.2 g sodium salt of (II) in 10 ml water with 5 ml 2% aqueous solution of p-toluidine; yield 0.17 g (91%). Orange needles (from aqueous alcohol), m. p. 231° (decomp.).

Found %: C 79.91; H 4.83; N 8.60. $C_{21}H_{16}O_2N_2$. Calculated %: C 76.82; H 4.91; N 8.53.

SUMMARY

1. 2-Nitroso-1-anthrol-4-sulfonic acid is formed by the action of hydrochloric acid on the bisulfite compound of 1,2-anthraquinonedioxime or on 1,2-anthraquinonedioxime-4-sulfonic acid, and by the action of hydroxylamine and hydrochloric acid on the bisulfite compound of 1-nitroso-2-anthrol or on 1,2-anthraquinone-4-sulfonic acid.

2. 2-Nitroso-1-anthrol-4-sulfonic acid resembles 2-nitro-1-anthrol-4-sulfonic acid in being stable to alkali and in not reacting with aromatic amines. It is converted by nitric acid into 2,4-dinitro-1-anthrol.

3. Treatment of 1-diazo-2-anthrol-4-sulfonic acid with sodium stannite leads to 2-anthrol-4-sulfonic acid; nitrosation of the latter gives 1-nitroso-2-anthrol-4-sulfonic acid.

4. Under the action of caustic alkali or aromatic amines, 1-nitroso-2-anthrol-4-sulfonic acid loses the sulfo group and forms, respectively, 1-nitroso-2,4-dihydroxyanthracene or 4-arylamino-1-nitroso-2-anthrol.

LITERATURE CITED

- [1] S. V. Bogdanov, J. Gen. Chem. 2, 9 (1932); S. V. Bogdanov and I. B. Migacheva, J. Gen. Chem. 19, 1490 (1949).
- [2] S. V. Bogdanov and M. V. Gorelik, J. Gen. Chem. 29, 140 (1959).*
- [3] S. V. Bogdanov and M. V. Gorelik, J. Gen. Chem. 29, 146 (1959).*
- [4] L. F. Fieser, J. Am. Chem. Soc., 50, 465 (1928).

Received March 3, 1958

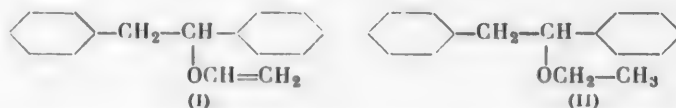
* Original Russian pagination. See C.B. Translation.

SYNTHESIS OF α -VINYLHYDROXYBIBENZYL

B. I. Mikhant'ev and L. P. Pavlov

Voronezh State University

In the course of a study of the vinylation of hydroxy compounds of the diphenylethane series with acetylene by the method of A. E. Favorskii and M. F. Shostakovskii [1], the authors obtained the vinyl ether of α -hydroxybiphenyl (phenylbiphenyl carbinol) (I). It was established that addition of acetylene proceeds with adequate speed at 160-170° in presence of potassium hydroxide. A secondary reaction at this temperature is the splitting out of water from α -hydroxybiphenyl with formation of stilbene, as already reported in the literature [2]. The vinyl ether and the product of its hydrogenation over skeletal nickel - α -hydroxybiphenyl ether ether (II) - resemble the starting alcohol in decomposing during normal distillation and also on heating with 20-30% sulfuric acid solution; in all cases stilbene is formed in good yield [2-4].



Preliminary experiments revealed the susceptibility of α -vinylhydroxybiphenyl to polymerization under the action of boron fluoride etherate with formation of highly viscous and solid resins. The ethyl ether is readily brominated with evolution of hydrogen bromide.

EXPERIMENTAL

Preparation of α -vinylhydroxybiphenyl. Into a rotating 1-liter autoclave were charged 29 g α -hydroxybiphenyl [5, 6] with m. p. 64.5-65.5°, 5.8 g potassium hydroxide powder and 290 ml toluene. Acetylene pressure on saturation 16 atm, duration of reaction 4 hr. The reaction mixture was washed with water, dried with potassium carbonate, and distilled. The 105-115° (1.25-2 mm) fraction was collected; this deposited crystals which were collected after freezing for 24 hr at -10°. Weight 4.90 g. Several recrystallizations from aqueous and then from undiluted alcohol gave 1.04 g (3.6%) α -hydroxybiphenyl with m. p. 63-64° (mixed-melting test; m. p. 63.5-64.5°) and 2.16 g (8.2%) stilbene with m. p. 123-124° (mixed-melting test; m. p. 123-124°). The filtrate (yellowish liquid, n_D^{20} 1.5657) was treated with sodium (48 hr, 15°), poured into the tenfold volume of dry ether, separated from precipitate, and distilled. Vinyl α -hydroxybiphenyl ether was obtained as a colorless liquid with a faint odor; yield 12.26 g (37.4%).

B. p. 107° (1 mm), 153.5° (10 mm), d_4^{20} 1.0235, n_D^{20} 1.5608, M_R 70.94; calc. 70.06.

Found %: C 86.04, 86.02; H 7.11, 7.17. M 217.2. $C_{16}H_{16}O$. Calculated %: C 85.68; H 7.19. M 224.3.

The vinyl ether decolorizes bromine and aqueous potassium permanganate solution. Oximation and quantitative hydrogenation demonstrated the presence of one vinyl group.

Hydrolysis. 1.80 g of the vinyl ether was heated with 200 ml 30% alcohol and 1 ml HCl (d 1.18) in an ampoule for 8 hr until the solution was homogeneous. The reaction was considerably accelerated by shaking and by addition of acetaldehyde-binding substances (sodium bisulfite, hydroxylamine). After dilution with

three volumes of water and cooling, 1.47 g (92.4%) substance with m. p. 63.5-64.5° (from aqueous alcohol) was isolated. A mixture with α -hydroxybiphenyl did not exhibit a depression of melting point.

Preparation of α -ethoxybiphenyl. 6.69 g α -vinylhydroxybiphenyl was hydrogenated with 0.5 g skeletal nickel in 20 ml alcohol. After the catalyst had been removed, the solvent was eliminated and the residue was vacuum-distilled to give 4.29 g (63.6%) of a colorless liquid with a very faint odor. It quickly decolorized bromine in carbon tetrachloride with evolution of hydrogen bromide, but did not decolorize aqueous potassium permanganate on shaking.

B. p. 93° (0.5 mm), 151.5° (10 mm), d_4^{20} 0.9987, n_D^{20} 1.5425, M_R 71.37; calc. 70.53.

Found %: C 84.83, 84.98; H 7.81, 7.83. $C_{16}H_{18}O$. Calculated %: C 84.91; H 8.02.

Literature data [3]; b. p. 149-151° at 10 mm.

SUMMARY

α -Vinylhydroxybiphenyl was synthesized from α -hydroxybiphenyl and was hydrogenated to α -ethoxybiphenyl.

LITERATURE CITED

- [1] A. E. Favorskii and M. F. Shostakovskii, J. Gen. Chem. 13, 1 (1943).
- [2] H. Limpricht and H. Schwanert, Lieb. Ann., 155, 62 (1870).
- [3] E. Späth, Monatsh. 35, 446 (1914).
- [4] M. Tuot, Bull. Soc. Chim., 1947, 1086.
- [5] C. Hell, Ber., 37, 453 (1904).
- [6] S. Siegel, S. K. Coburn, and D. R. Levering, J. Am. Chem. Soc. 73, 3163 (1951).

Received March 1, 1958

INVESTIGATION OF MIXED ETHYLENIC ACETYLENIC γ -GLYCOLS

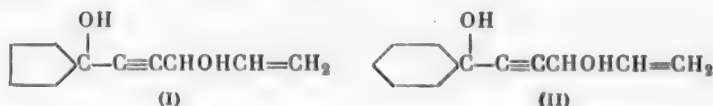
A. I. Nogaideli, K. Ya. Dzagnidze, T. Pagava and
T. Kverenchkhiladze
Tbilisi State University

Synthesis and Catalytic Hydrogenation of 5-(1-Hydroxycyclopentyl)-1-penten-4-yne-3-ol and 5-(1-Hydroxycyclohexyl)-1-penten-4-yne-3-ol

Our earlier investigations had shown that ethynylcarbinol magnesium bromides react with unsaturated aldehydes to form acetylenic ethylenic glycols in yields of up to 50%. A study was made of the character of the catalytic hydrogenation of these acetylenic ethylenic glycols [1].

In the present work we investigated the reaction of acrolein with the Grignard reagents from 1-hydroxycyclopentylacetylene and 1-hydroxycyclohexylacetylene, and we studied the catalytic hydrogenation of the resulting acetylenic ethylenic glycols.

Our investigations showed that normal products of the reactions are formed in the shape of the acetylenic ethylenic secondary-tertiary glycols; 5-(1-hydroxycyclopentyl)-1-penten-4-yne-3-ol (I) and 5-(1-hydroxycyclohexyl)-1-penten-4-yne-3-ol (II) in 50% yield.



In presence of platinum black, these acetylenic ethylenic glycols undergo hydrogenation at uniform speed with addition of 6 atoms of hydrogen to give the corresponding saturated γ -glycols. In presence of colloidal palladium, however, hydrogenation goes very much faster and also nonuniformly. Addition of 4 atoms of hydrogen at first occurs intensively, but subsequently 2 more atoms of hydrogen are taken up very much more slowly. For example in presence of 6 mg palladium 0.01 mole glycol (I) combines with 4 atoms of hydrogen in 6 minutes, whereas addition of the remaining 2 atoms of hydrogen extends over a period of 21 minutes. Under similar conditions the acetylenic ethylenic glycol (II) adds on 4 atoms of hydrogen in 6 minutes and the remaining 2 atoms of hydrogen in 65 minutes.

The character of the hydrogenation of acetylenic ethylenic glycols containing cyclic radicals is therefore similar to that of hydrogenation of open-chain acetylenic ethylenic glycols, although the effect of the weight of the radical is to slow down the hydrogenation after addition of four atoms of hydrogen.



In presence of platinum black as well as of colloidal palladium, the products of exhaustive hydrogenation are the saturated γ -glycols: 5-(1-hydroxycyclopentyl)-3-pentanol (III) and 5-(1-cyclohexyl)-3-pentanol (IV).

EXPERIMENTAL

Synthesis of 5-(1-hydroxycyclopentyl)-1-penten-4-yne-3-ol (I). The usual method was used, the reactants being 25 g magnesium, 109 g ethyl bromide, 56 g 1-hydroxycyclopentylacetylene and 3 g acrolein. An oily liquid was obtained in 50% yield.

B. p. 128-132° (3-4 mm), d_{20}^{25} 1.068, n_D^{25} 1.500, MR_D 46.48; calc. 46.75.

Found % C 71.80; H 8.22; OH 19.46. M 162. $C_{10}H_{14}(OH)_2$. Calculated % C 72.20; H 8.43; OH 20.48. M 166.

Synthesis of 5-(1-hydroxycyclohexyl)-1-penten-4-yne-3-ol (II). The glycol was prepared from 12 g magnesium, 56 g ethyl bromide, 31 g 1-hydroxycyclohexylacetylene and 25 g acrolein in 45% yield.

B. p. 143-144° (3-4 mm), d_{20}^{25} 1.064, n_D^{25} 1.5128, MR_D 50.95; calc. 51.37.

Found % C 72.80; H 8.80; OH 18.7. M 184. $C_{11}H_{14}(OH)_2$. Calculated % C 73.30; H 8.80; OH 18.88. M 180.

TABLE 1

Hydrogenation of Glycol (I)

Expt. No.	Weight (in g)	Catalyst (in mg)	Hydrogen (in ml)		
			found	calc.	Volume taken up each 6 minutes
1	1.57	Pt-black 750	635	636	129, 93, 73, 48, 29, 19, etc; in all 658 ml after 207 min.
2	1.82	Pd-colloidal palladium 5	778	780	480, 220, 100, 23.7; in all 780 ml after 27 min.

TABLE 2

Hydrogenation of Glycol (II)

Expt. No.	Weight (in g)	Catalyst (in mg)	Hydrogen (in ml)		
			found	calc.	taken up after each 6 min.
1	1.63	Pt-black 900	609	643	200, 130, 70, 45, etc.; in all 643 ml in 135 min.
2	1.80	Pd-colloidal palladium 5	749	759	520, 149, 17, etc.; in all 759 ml in 71 min.

Hydrogenation of 5-(1-hydroxycyclopentyl)-1-penten-4-yne-3-ol was performed in 50 ml ethanol in presence of platinum black and colloidal palladium (Table 1).

After suitable working-up, the product of hydrogenation was distilled to give a mobile, oily substance in 94% yield.

B. p. 80-82° (4-5 mm), d_{20}^{20} 0.9197, n_D^{20} 1.4638, MR_D 49.71; calc. 49.23.

Found %: C 69.25; H 11.32; OH 17.4. $C_{10}H_{14}(OH)_2$. Calculated %: C 69.76; H 11.68; OH 19.7.

Hydrogenation of 5-(1-hydroxycyclohexyl)-1-penten-4-yne-3-ol. This glycol was hydrogenated in 50 ml ethanol in presence of platinum black and colloidal palladium. Results are set forth in Table 2.

A mobile, transparent oil was obtained in 95% yield.

B. p. 109-122° (4 mm), d_{20}^{20} 0.9560, n_D^{20} 1.4745, MR_D 54.00; calc. 54.58.

Found %: C 70.10; H 11.10; OH 16.0. M 180. $C_{11}H_{20}(OH)_2$. Calculated %: C 70.90; H 11.80; OH 18.2. M 186.

SUMMARY

The following acetylenic ethylenic glycols were prepared for the first time and characterized: 5-(1-hydroxycyclopentyl)-1-penten-4-yne-3-ol and 5-(hydroxycyclohexyl)-1-penten-4-yne-3-ol.

The character of the hydrogenation of these acetylenic ethylenic glycols in presence of platinum black and colloidal palladium was studied.

5-(1-Hydroxycyclopentyl)-3-pentanol and 5-(1-hydroxycyclohexyl)-3-pentanol were described for the first time.

LITERATURE CITED

[1] A. I. Nogaideli, K. Ya. Dzagnidze and N. Uridiya, J. Gen. Chem., 25, 2225 (1955);* A. I. Nogaideli, K. Ya. Dzagnidze, and R. Papava, J. Gen. Chem., 28, 116 (1958).*

Received March 25, 1958

* Original Russian pagination. See C.B. Translation.

REACTIONS OF HALONITROPARAFFINS WITH OLEFINS

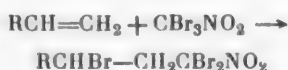
Yu. A. Baskakov and N. N. Mel'nikov

Institute of Plant Physiology of the Academy of Sciences of the USSR

One of the interesting methods of preparation of polyhaloparaaffins is the addition of chloroform, carbon tetrachloride and other halogenated derivatives to olefins and haloolefins [1]. This reaction is of great interest because it permits the preparation of various compounds that could not be easily obtained by other methods. It has been employed in a large number of preparations, including the addition to olefins of various substances containing not only halogens but also other functional groups [2]. Nevertheless, the literature contains no information about the interaction of halonitroparaaffins with olefins. At the same time great interest is attached to the study of the reaction of olefins with halonitroparaaffins in which the halogen and the nitro group are attached to the same carbon atom, since the behavior of these compounds is markedly different from that of the usual polyhalo derivatives [3-7].

We therefore undertook a study of the reaction of halonitroparaaffins with olefins. Such a study seemed likely also to be of practical interest for the synthesis of weed killers and plant-growth regulators.

As the olefinic components we took 1-hexene, cyclohexene, 1-heptene, 1-octene and 1-isooctene. These were reacted with chloronitromethane, dichloronitromethane, chloropicrin, bromonitromethane, tribromonitromethane and 1,1-dichloro-1-nitroethane. The reactions were conducted both with exposure to ultraviolet light and in presence of benzoyl peroxide. As was to be expected, due to the presence of a semi-polar bond in the nitro compounds, halonitroparaaffins react very slowly with olefins. In our conditions only tribromonitromethane reacts with olefins with appreciable speed. This reaction may be represented by the general equation:



In this manner we synthesized several tribromonitroparaaffins which had not been described in the literature. Their properties are presented in the table. Bromocyclohexyldibromonitromethane breaks down on distillation in high vacuum. We therefore isolated it in the unpurified state and the analyses were unsatisfactory. We have therefore omitted the data for the product of condensation of bromopicrin with cyclohexene.

EXPERIMENTAL

Condensation of halonitroparaaffins with the above-mentioned olefins was carried out in the majority of cases in a flask with a reflux condenser in a nitrogen atmosphere and with heating on an air bath. The halonitroparaffin was used in considerable excess (2 to 5 moles per mole of olefin) in order to exclude formation of products of condensation with several molecules of olefin. After completion of reaction, the mixture was fractionated in high vacuum and the product was analyzed. The products that we synthesized and their properties are listed in the table. In cases when the reaction did not go in presence of benzoyl peroxide, a fresh experiment was run with exposure to the light of a PRK-2 or PRK-4 quartz mercury lamp.

Properties and Analyses of Tribromonitroparaffins

Name	Yield (in %)	B. P. (pressure in mm)	d_4^{20}	n_D^{20}	MR _r		Found (%)				Calculated (%)			
					found	calc.	C	H	N	Br	C	H	N	Br
1,1,3-Tribromo-1-nitroheptane	51	74-75° (0.03)	1.8745	1.5348	63.41	63.44	22.02, 22.19	3.39, 3.45	3.68, 3.37	62.91, 62.63	22.01	3.16	3.66	62.77
1,1,3-Tribromo-1-nitrooctane	57	68-73 (0.01)	1.7959	1.5304	68.14	68.05	24.31, 24.32	3.59, 3.52	3.56, 3.39	60.32, 60.83	24.26	3.56	3.54	60.55
6-Methyl-1,1,3-tri-bromo-1-nitroheptane	44	65-68 (0.02)	1.7793	1.5275	68.47	68.05	24.15, 24.31	3.52, 3.62	3.48, 3.28	60.71, 60.18	24.26	3.56	3.54	60.55
4,4,3-Tribromo-1-nitrononane	73	92-95 (0.04)	1.7284	1.5240	72.59	72.68	25.97, 26.12	4.02, 4.27	3.36, 3.35	57.79, 57.77	26.36	3.94	3.42	58.47

* In Russian.

The mixture of chloropicrin and hexene, for example, was irradiated with the quartz mercury lamp for 80 hr. Appreciable quantities of condensation products could not, however, be isolated by fractionation. Similar results were obtained with mono- and dihalonitromethanes.

SUMMARY

The reaction of halonitroparaffins with some olefins was studied. It was shown that the reaction goes very much more slowly than the reaction of the the corresponding polyhaloparaffins with olefins. This effect is brought about by the presence of a semipolar bond which hinders formation of radicals and promotes chain breakage.

A number of tribromonitroparaffins not previously described in the literature were synthesized by reaction of tribromonitromethane with olefins.

LITERATURE CITED

- [1] B. A. Arbuzov, Reactions and Methods of Investigation of Organic Compounds [in Russian] (State Chemical Press, 1952), Vol. 2, p. 7.*
- [2] M. S. Kharasch, P. S. Skell, and P. Fischer, J. Am. Chem. Soc. 78, 1058 (1948).
- [3] V. V. Nekrasov and N. N. Mel'nikov, J. Russ. Chem. Soc., 61, 2049 (1929).
- [4] A. E. Kretov and N. N. Mel'nikov, J. Gen. Chem. 2, 202 (1932).
- [5] N. N. Mel'nikov, J. Gen. Chem. 4, 1016 (1934).
- [6] N. N. Mel'nikov, J. Gen. Chem., 7, 456 (1937).
- [7] N. N. Mel'nikov, J. Gen. Chem. 7, 1546 (1937).

Received February 18, 1958

JUTE GLYCOSIDES

II. THE STRUCTURE OF OLITORISIDE

N. K. Abubakirov, V. A. Maslennikova and M. B. Gorovits

Institute of the Chemistry of Plant Substances of the Academy of Sciences of the Uzbek SSR

We isolated olitoriside from the seeds of *Corchorus olitorius* L. The formula $C_{35}H_{53}O_{14}$ was proposed on the basis of our analytical data. It was shown that olitoriside is a diglycoside and breaks down to a sugar residue and strophanthidine under the action of acids [1].

In the present paper we submit the results of data permitting elucidation of the structure of olitoriside. The problem was to establish the nature and the sequence of addition of the two sugar residues to the molecule of strophanthidine. With this objective we cleaved olitoriside with the help of various enzymes. In this connection we made use of emulsin, a ferment (corchoriase) present in jute seeds themselves, and a ferment solution definitely free of any cardiac glycosides obtained from lucerne seeds. After treatment with emulsin, olitoriside was recovered unchanged; treatment with the other two agents led to the same result - formation of a new compound. The latter was likewise a glycoside; it had the empirical formula $C_{29}H_{41}O_9$, i. e., it contained one hexose molecule less than the original substance. It was named desgluco-olitoriside. Unlike olitoriside (I, R = H), desglucoolitoriside (III, R = H) gives a very marked Keller-Kiliani reaction, which confirmed the earlier hypothesis [1] that the sugar closest to the genin must be a 2-desoxy sugar. Desgluco-olitoriside gives a diacetyl derivative (IV, R = COCH₃).

Mild acidic hydrolysis of desgluco-olitoriside leads to formation of strophanthidine $C_{23}H_{32}O_6$ (VI) and 2-desoxymethylpentose $C_5H_{10}O_4$ (V) with m. p. 91-93° and $[\alpha]_D^{20} -12.3^\circ$ (in methanol). Out of the eight isomeric 2-desoxymethylpentoses, the constants of the sugar that we had obtained were closest to those of D-boivinose [2] (VII) - the sugar component of stroboside, a glycoside from *Rouppelia Boivinii* (synonym: *Strophanthus Boivinii*). It was shown by synthesis [3] that D-boivinose is D-xylo-2-desoxy-hexamethylse. Although for lack of an authentic specimen we were unfortunately unable to make a direct comparison of the sugar obtained by hydrolysis of desgluco olitoriside with D-boivinose, there can be no doubt that they are identical.

Among the glycosides isolated from jute seeds, we may direct attention to corchoroside A, first described by Frerejacque and Durgeat [4]. Recently this cardiac glycoside has twice been the subject of investigation [5, 6]. Comparison between the physicochemical constants of the glycosides themselves, the acetyl derivatives and the products of hydrolysis of corchoroside A, glycoside A and desgluco-olitoriside also afford convincing evidence of their identity (Table 1).

For detection of the second sugar component use was made of the pancreatic juice of the snail *Helix plectropis* (normally the juice of the large snail *Helix pomatia* is used for this purpose). Fermented masses of jute and lucerne proved very unsuitable since they themselves contained sugar. Fermentative hydrolysis with the gastric juice of the snail gave the same desgluco-olitoriside (III), and D-glucose (V) was detected in aqueous solution by paper chromatography. The latter was isolated and identified in the form of the osazone.

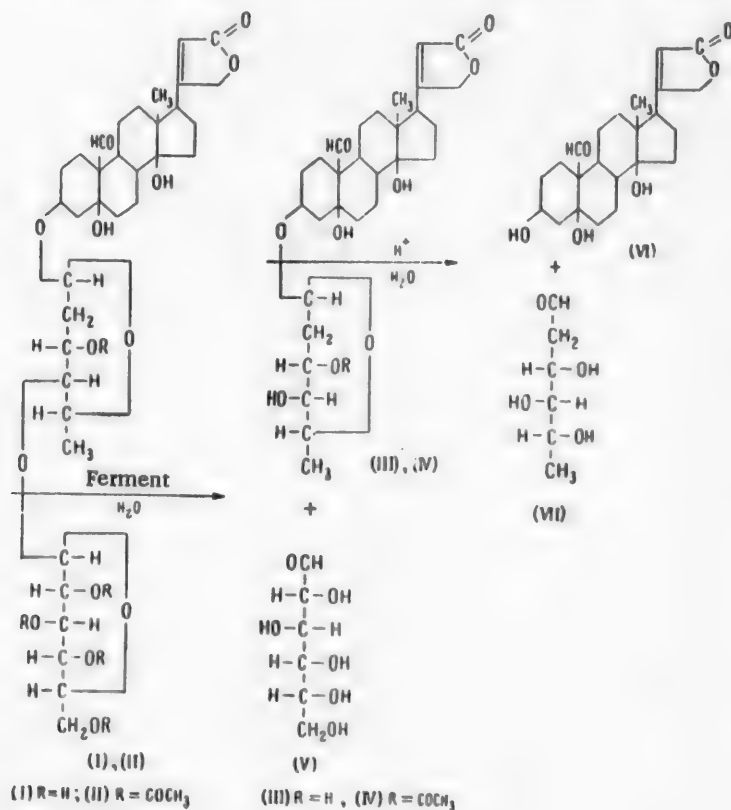
Kreis, Tamm and Reichstein [5] arrived at the conclusion that in corchoroside A the sugar is linked to the aglucone by a β -glycosidic bond. Comparison of the molecular rotations shows that in olitoriside, in conformity with the Klyne rule [7], D-glucose is attached to desoxy-olitoriside by a β -glycosidic bond (Table 2).

TABLE 1

Constants	Corchoroside A [4]	Corchoroside A [5]	Glycoside A [6]	Desgluco-olitoriside
Glycoside				
Formula	$C_{29}H_{42}O_9$	$C_{29}H_{42}O_9$	$C_{29}H_{42}O_9$	$C_{29}H_{42}O_9$
Melting point	188—90°	163—68°	190—91°	165—166°
$[\alpha]_D$ in methanol	+11°	+18.4°	+11.8°	+17.1°
Acetyl derivatives				
Melting point	166°	141—45°	213—214°*	156—161°
$[\alpha]_D$ in chloroform	—	+25.4°	—	+23.3°
Aglucone	Strophanthidine			
Sugar component	2-Desoxysugar	d-Boivinose	—	d-Boivinose

*Only V. K. Orlov and G. V. Lazur'evskii [6] mention the preparation of a monoacetyl derivative. The remaining authors obtained diacetyl derivatives.

Olitoriside (I, R = H) is consequently strophanthidine-(3)- β -D-boivinoside- β -D-glycoside. Out of all of the cardiac glucosides its structure is closest to that of strophanthin K, and it differs from the latter only by the structure of the molecule of the 2-desoxy sugar enclosed between the D-glucose and the strophanthidine. It is



extremely probable that the corchoriside A isolated from jute seeds by other workers is a fragment of olitoriside or even of a triglycoside even richer in sugars and not yet described. The hydrolytic cleavage of olitoriside may be represented by the preceding scheme.

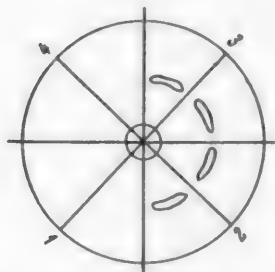
TABLE 2

Substance	M	$[\alpha]_D$	$[M]_D = \frac{M \cdot [\alpha]_D}{100}$
Olitoriside	696.80	$-4.5^\circ \pm 1^\circ$	$-31^\circ \pm 7^\circ$
Desgluco-olitoriside	534.65	$+17.1^\circ \pm 1^\circ$	$+91^\circ \pm 5^\circ$
Contribution of the rotation of d-glucose	—	—	$-122^\circ \pm 12^\circ$
α -Methyl-d-glycoside (1,5) [8]	194.19	$+158.9^\circ$	$+309^\circ$
β -Methyl-d-glycoside (1,5) [8]	194.19	-34.2°	-66°

EXPERIMENTAL

Fermentative Cleavage of Olitoriside

a) With jute ferments. 20 g pulverized and defatted seeds were steeped for 3 hr in 60 ml water at 0° . Expression of the seed mass yielded 15 ml of glutinous aqueous solution. The latter was diluted with 100 ml water and mixed with 0.45 g olitoriside in 5 ml ethanol. The reaction mass was kept in a thermostat at $34-35^\circ$ for 40 hr, then diluted with 100 ml methanol and filtered. The filtrate was evaporated to 20 ml in vacuo, made up to 80 ml with methanol, and treated with freshly prepared (from 80 g basic lead acetate) lead hydroxide. The filtered solution was acidified with 10% H_2SO_4 to pH 6, filtered, evaporated in vacuo to 20 ml, and repeatedly extracted with chloroform. The extract was washed with saturated sodium carbonate solution and then with water. Thereupon the aqueous layer commenced to deposit crystals of desgluco-olitoriside (0.12 g). Evaporation of the chloroform solution yielded another 0.17 g of desgluco-olitoriside.



Radial paper chromatography. Olitoriside before fermentation (1), olitoriside after fermentation (2), D-glucose (3), and the digestive juice of the snail (4).

b) With lucerne ferments. 100 g pulverized and defatted lucerne seeds was steeped for 3 hr in 300 ml water at 0° . 32 ml of the aqueous extract, obtained by expression of the seed mass, was mixed with 100 ml water and a solution of 0.57 g olitoriside in 5 ml ethanol. Further treatment was as described for fermentation with jute ferments. 0.36 g desgluco-olitoriside was obtained.

c) With the pancreatic juice of *Helix plectotropis*. Preparation of snail ferment. Snails were placed in a jar to the very top which was filled a 0.8% aqueous solution of ethylurethane or with water which had been well boiled and then cooled to $40-45^\circ$. They were then left for 24 hr. The snails died in a straightened form. The shell was gently broken with a small hammer and the fine splinters removed with a pipet. The spiral helix was carefully unrolled; the gullet leading to the stomach was located, and the reddish-brown liquid squeezed through the oral opening. Ten snails usually yield 0.5 ml gastric juice. The juice retains its activity for several weeks in presence of a drop of toluene at 0° or -10° .

0.40 g olitoriside in 2 ml ethanol was mixed with 0.5 ml digestive juice of the snail in 250 ml water, and the solution was kept 35 hr in a thermostat at $34-36^\circ$. The water was then driven off in vacuo, and 20 ml ethanol was run into the dry residue. The alcoholic solution was filtered from the insoluble ferments, evaporated to 2 ml in vacuo, and diluted with 2 ml water. After many hours' standing, the solution deposited acicular crystals of desgluco-olitoriside. Yield 0.30 g.

0.002 ml of the mother liquor was subjected to radial paper chromatography. The mobile phase was n-butyl alcohol saturated with water. Period of chromatography 3 hr. o-Toluidine was used as developer. D-Glucose was developed (see diagram).

The mother liquor was concentrated to 2 ml and mixed with 0.2 g phenylhydrazine hydrochloride and 0.3 g sodium acetate in 2 ml water. After approximately 1 hour's heating at 100°, yellow needles came down; m. p. 205° (from ethanol). A mixture with the osazone of D-glucose did not give a depression of melting point.

Desgluco-olitoriside

Desgluco-olitoriside comes down from aqueous methanol (1 : 1) in the form of colorless, elongated prisms containing 2 molecules of crystal water.

Found %: H₂O 6.11. C₂₉H₄₂O₉ · 2H₂O. Calculated %: H₂O 6.31.

After numerous recrystallizations and after drying in vacuo, desgluco-olitoriside had m. p. 165-166°, [α]_D¹⁸ + 17.1° ± 1° (c 3.315 in methanol). Desgluco-olitoriside is readily soluble in ethyl and methyl alcohols, sparingly soluble in chloroform and water, insoluble in ether. The glycoside gives a positive Keller-Kiliani reaction. The following colors were progressively developed with 84% H₂SO₄: 0°, greenish-brown; 15°, yellow-brown; 2 hr, grey-green. Prior to analysis the substance was dried in vacuo over P₂O₅ at 105° until constant in weight.

Found %: C 65.42, 65.31; H 8.23, 8.15. C₂₉H₄₂O₉. Calculated %: C 65.15; H 7.92.

Di-O-acetyl-desgluco-olitoriside. A solution of 0.7 g desgluco-olitoriside in a mixture of 16 ml pyridine and 12 ml acetic anhydride was held at 40° for 30 hr. After the excess of reactants had been driven off in vacuo, the residue was dissolved in methanol. Water was added to bring down the acetyl derivative, which was then recrystallized from aqueous methanol (1 : 1). Yield 0.46 g.

M. p. 159-161°; [α]_D¹⁸ + 23.3° ± 1° (c 2.656 in chloroform).

Found %: C 62.53, 62.52; H 7.71, 7.97. C₃₃H₄₆O₁₁ · H₂O. Calculated %: C 62.24; H 7.60.

Acid hydrolysis of desgluco-olitoriside. 2.0 g glycoside in 30 ml methanol was mixed with 30 ml 0.1 N H₂SO₄ and heated 1 hr at 80-85°. After the methanol had been distilled off in vacuo, the solution deposited crystals (1.26 g). The latter was identified as strophanthidine [1] by the mixed-melting test, by color reactions and by the magnitude of the rise on the paper chromatogram. After the crystals had been isolated, the aqueous solution was extracted many times with chloroform and then neutralized with freshly prepared BaCO₃. The sugar solution, after filtration from the BaSO₄, was evaporated to a syrup in vacuo. After several days the syrup crystallized. Threerecrystallizations from a mixture of methanol and acetone gave 0.17 g sugar, which after drying over P₂O₅ in vacuo had m. p. 91-93°; [α]_D¹⁸ -12.3 ± 2° (c 1.626 in methanol); after 48 hr it had [α]_D¹⁸ -1.8°.

The authors who have described D-boivinose report m. p. 100-103° [2], 96-98° [3] and 76-81° [5]; they say that the melting point of boivinose depends on the previous treatment and on the humidity of the surrounding air; [α]_D²⁰ -10.4° ± 2° (in methanol) [5].

SUMMARY

Fermentative hydrolysis of olitoriside C₃₅H₅₂O₁₄ - a diglycoside from the seeds of *Corchorus olitorius* L. - leads to detachment of D-glucose with formation of desgluco-olitoriside C₂₉H₄₂O₉. Mild acid hydrolysis of the latter leads to D-boivinose and strophanthidine. Comparison of the molecular rotation shows that in both of the cases the sugars are attached by a β -glucosidic bond. These reactions established the structure of olitoriside as strophanthidine-(3)- β -D-boivinoside- β -D-glucoside.

LITERATURE CITED

- [1] N. K. Abubakirov, V. A. Maslennikova and M. B. Gorovits, Proc. Acad. Sci. Uzbek SSR, 6, 23 (1957); J. Gen. Chem. 28, 2279 (1958).
- [2] O. Schindler and T. Reichstein, Helv. Chim. Acta. 35, 730 (1952).
- [3] H. R. Bolliger and T. Reichstein, Helv. Chim. Acta, 36, 302 (1953).
- [4] M. Frerejacque and M. Durgeat, C. r., 238, 507 (1954).

*Original Russian pagination. See C.B. Translation.

- [5] W. Kreis, Ch. Tamm, and T. Reichstein, *Helv. Chim. Acta.*, 40, 593 (1957).
- [6] V. K. Orlov and G. V. Lazur'evskii, *Sci. Memoirs Kishin. State Univ.*, 27, 3 (1957).
- [7] W. Klyne, *Bloch. J.* 47, 41 (1950).
- [8] C. Ribber, *Ber.* 57, 1797 (1924).

Received March 18, 1958

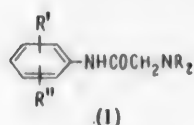
ARYLAMIDES OF DIALKYLAMINOACETIC ACIDS

N. I. Kudryashova, A. L. Remizov and

N. V. Khromov-Borisov

Institute of Experimental Medicine of the Academy of Medical Sciences of the USSR

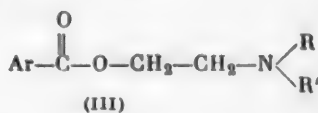
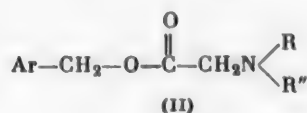
In this paper we describe the synthesis of a series of arylamides of dialkylaminoacetic acids with the general formula (I), together with the results of measurements of the dissociation constants of these compounds.



Dialkylaminoacyl derivatives of various aromatic amines have recently been a focus of interest for chemists and pharmacologists due to their properties as local anesthetics.

A current hypothesis in pharmacology is that the active principles of local anesthetics are the bases formed by hydrolysis of the corresponding salts which are introduced into the organism in the form of their aqueous solutions. It was therefore also important to measure the dissociation constants of these compounds.

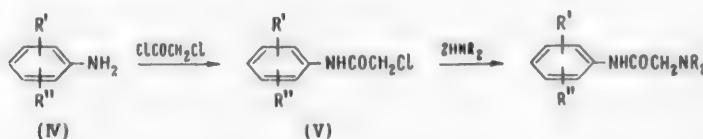
It should be mentioned that a comparative study of the basicity on the one hand and of the intensity of the local-anesthetic action of dialkylaminoacetic esters of fatty-aromatic alcohols (II) and of the isomeric esters of dialkylaminoethanols with aromatic and fatty-aromatic acids (III) on the other hand revealed a very appreciable dependence of the pharmacological activity of these compounds on their basicity constants [1].



In a series of compounds of the type of (I) it was interesting to find a change in pharmacological activity with the number, position and character of the R' and R'' radicals in the benzene ring, and also an influence of the change of structure of the dialkylamino group NR₂.

The substituents R' and R'' in our compounds were H, CH₃, NO₂, NH₂ and N(CH₃)₂, while NR₂ was represented by the diethylamino and piperidine radicals.

Synthesis was effected in two steps.



The starting aromatic amines (IV) were aniline, o- and p-toluidines, m-4- and m-2-xylydines, p-nitroaniline and dimethyl-p-phenylenediamine. The amides of monochloroacetic acid (V) prepared from these

TABLE 1
R-NHCOCH₂NR';

Pre- para- tion no.	R	NR'	Base			Hydrochloride			Methiodide		
			b. p. (pressure in mm)	melting point	yield (in %)	melting point	% Cl		melting point	% N	
							found	calc.		found	calc.
1	C ₆ H ₅	N(C ₂ H ₅) ₂	130-131°(2.5)[²]		93	109-110°	14.66	14.61	125-127°	8.05	8.04
2	C ₆ H ₅	NC ₃ H ₁₀	—	95-96°[²]	95	182-184	13.96	13.92	155-157	7.76	7.78
3	2-CH ₃ C ₆ H ₄	N(C ₂ H ₅) ₂	138(2.5)[²]	—	89.5	118-119	13.84	13.80	104-105	7.78	7.73
4	2-CH ₃ C ₆ H ₄	NC ₃ H ₁₀	—	94-97[⁴]	86	173-176	13.34	13.19	189-191	7.58	7.49
5	4-CH ₃ C ₆ H ₄	N(C ₂ H ₅) ₂	143(2)[⁴]	—	72	150-152	13.90	13.80	146-147	7.58	7.73
6	4-CH ₃ C ₆ H ₄	NC ₃ H ₁₀	168-170(2)	67-69	76.5	214-216	13.34	13.19	165-167	7.24	7.49
7	2,4-(CH ₃) ₂ C ₆ H ₃	N(C ₂ H ₅) ₂	152-153(2)[⁴]	—	91	95-98	13.17	13.09	127-128	7.48	7.45
8	2,4-(CH ₃) ₂ C ₆ H ₃	NC ₃ H ₁₀	—	82-85	87	200-202	12.36	12.53	215-216	7.29	7.21
9	2,6-(CH ₃) ₂ C ₆ H ₃	N(C ₂ H ₅) ₂	167(3)[⁴]	65-67	80	128-129	13.12	13.09	154-155	7.45	7.45
10	2,6-(CH ₃) ₂ C ₆ H ₃	NC ₃ H ₁₀	—	114-117[³]	80	177-178	12.24	12.53	206-208	7.17	7.21
11	4-NO ₂ C ₆ H ₄	N(C ₂ H ₅) ₂	—	67-68[⁵]	95	226-229	12.34	12.32	210-212	10.56	10.78
12	4-NO ₂ C ₆ H ₄	NC ₃ H ₁₀	—	144.5-145	84	256-257	11.74	11.82	243.5-245	10.34	10.37
13	4-NH ₂ C ₆ H ₄	N(C ₂ H ₅) ₂	203-204(2.5)[⁵]	—	84.5	214-217	13.66	13.76	—	—	—
14	4-NH ₂ C ₆ H ₄	NC ₃ H ₁₀	—	107-108	76	223-225	13.43	13.14	—	—	—
15	4-N(CH ₃) ₂ C ₆ H ₄	N(C ₂ H ₅) ₂	182(3.5)[⁶]	—	80	217-220*	22.12	22.00	155(decomp.)	8.00	7.88
16	4-N(CH ₃) ₂ C ₆ H ₄	NC ₃ H ₁₀	—	98-100	91	—	—	—	—	—	—

* Dihydrochloride.

** Dimethiodide.

TABLE 2

Pre-para- tion No.	Formula	pK _a in water at 20°	pK _c in 30% alcohol at 23°	Duration of local anes- thetic activ- ity (in min.)	Pre-para- tion No.	Formula	pK _a in water at 20°	pK _c in 30% alcohol at 23°	Duration of local anes- thetic activ- ity (in min.)
1	C ₆ H ₅ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	8.00	7.60	10	9	C ₆ H ₅ NHCOCH ₂ NC ₅ H ₁₀ **	7.85	7.50	5
2	2-CH ₃ C ₆ H ₄ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	8.00	7.55	15	10	2-CH ₃ C ₆ H ₄ NHCOCH ₂ NC ₅ H ₁₀	7.70	7.35	10
3	4-CH ₃ C ₆ H ₄ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	8.13	7.80	15	11	4-CH ₃ C ₆ H ₄ NHCOCH ₂ NC ₅ H ₁₀	7.85	7.45	10
4	2,4-CH ₃ ₂ C ₆ H ₃ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	7.95	7.50	30	12	2,4-CH ₃ ₂ C ₆ H ₃ NHCOCH ₂ NC ₅ H ₁₀	7.80	7.35	30
5	2,6-CH ₃ ₂ C ₆ H ₃ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	7.85	7.70	70	13	2,6-CH ₃ ₂ C ₆ H ₃ NHCOCH ₂ NC ₅ H ₁₀	7.60	7.30	50
6	4-NO ₂ C ₆ H ₄ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	8.05	7.70	0	14	4-NO ₂ C ₆ H ₄ NHCOCH ₂ NC ₅ H ₁₀	***	7.50	0
7	4-NH ₂ C ₆ H ₄ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	8.15	7.90	15	15	4-NH ₂ C ₆ H ₄ NHCOCH ₂ NC ₅ H ₁₀	7.90	7.70	10
8	4-N(CH ₃) ₂ C ₆ H ₃ NHCOCH ₂ NC ₂ H ₅ ^{1/2}	8.05	7.75	10	16	4-N(CH ₃) ₂ C ₆ H ₃ NHCOCH ₂ NC ₅ H ₁₀	7.80	7.50	10
9	Novocain	8.85[9]		19					

* Pharmacological tests of all of the compounds were performed by P. E. Motovilov [10].

** NC₅H₁₀ - piperidyl

*** Determination of the dissociation constant in water was impossible due to the nearly complete insolubility of the base under these conditions.

amines were brought into reaction in the second step with diethylamine and piperidine. The so-synthesized bases were converted to the hydrochlorides and methiodides.

Table 1 contains details of all of the synthesized compounds.

The dissociation constants of our compounds were calculated from data for potentiometric titration of solutions of their hydrochlorides. Allowance was made for the active concentration of ions, so that the calculated values of the constants approximate to the thermodynamic values. Comparison of the data for the basicity of the investigated preparations with their pharmacological activity indicated that the latter is not a linear function of the basicity (Table 2).

It is interesting to note that the basicity of the investigated compounds is not directly proportional (as might have been expected) but inversely proportional to the basicity of the amine from which they are derived. Whereas diethylamine is slightly less basic than piperidine (diethylamine has pK_a 10.98 and piperidine has a value of 11.21), all of the arylamides of diethylaminoacetic acid are stronger bases than the corresponding arylamides of piperidineacetic acid.

On the basis of the data obtained, we can conclude to a first approximation that the increase in polarity of the lipophilic portion of the molecule (the aromatic radical) by introduction of a nitro-, amino or dimethylamino group leads to a sharp fall in, or even to complete disappearance of, anesthetic activity. On the other hand, enlargement of the lipophilic portion of the molecule by introduction of a methyl group has the opposite effect.

EXPERIMENTAL

1. Preparation of amides of monochloroacetic acid. Method A. 0.1 mole amine and 85 ml glacial acetic acid were placed in a flask and cooled to 10°; 0.11 mole chloroacetyl chloride was then added quickly; thereupon, 33 g CH₃COONa • 3H₂O in 140 ml water was added to the transparent solution. The mixture was stirred 30 min, the precipitate was filtered off, washed several times with water, dried and recrystallized from aqueous alcohol or acetone. By this method we prepared the chloroacetyl derivatives of aniline, o- and p-toluidines, and m-4- and m-2-xylydines in yields of 65.5, 76.5, 80, 65.4 and 76%, respectively.

Method B. 0.1 mole amine was dissolved in 50-100 ml acetone; the solution was cooled with snow, and dropwise addition was gradually made of 0.055 mole chloroacetyl chloride followed by 50 ml 2 N NaOH, and then (dropwise) by a further 0.055 mole chloroacetyl chloride. The reaction mixture was diluted with water; the precipitate was filtered off, washed with water, dried, and recrystallized. By this method we obtained the chloroacetyl derivatives of aniline, o-toluidine, m-4-xylidine, p-nitroaniline and p-dimethylaminoaniline in yields of 77.7, 87, 70, 94 and 85%, respectively.

2. Amination of amides of monochloroacetic acid. Into a round-bottomed flask with a reflux condenser, fitted with a calcium chloride tube, were charged 0.1 mole chloroacetyl derivative of the amine, 50-60 ml anhydrous benzene and 0.26 mole diethylamine or piperidine. The mixture was boiled 5 hr, after which the precipitate of diethylamine hydrochloride or piperidine hydrochloride was filtered off, washed with dry benzene, dried, and weighed. The yield of hydrochloride was nearly theoretical. The benzene and excess amine were distilled off; the residue was distilled in vacuo, or (if crystalline) recrystallized from aqueous alcohol or ligroin.

3. Preparation of ω -diethylamino-4-aminoacetanilide. Preparation was effected by reduction of ω -diethylamino-4-nitroacetanilide with hydrazine hydrate in presence of Raney nickel [8]. Into a round-bottomed flask, fitted with a mechanical stirrer, reflux condenser and thermometer, were charged 2.68 g ω -diethylamino-4-nitroacetanilide, dissolved in 100 ml alcohol, and 4 ml 90% hydrazine hydrate. The reaction mass was heated to 40° and a little Raney nickel was added. The temperature rose to 50°. The flask was heated 1 hr on a water bath at 75° and then cooled. The catalyst was filtered off and washed with alcohol; the alcohol was driven off. The residue was distilled in vacuo. B. p. 203-204° (3.5 mm). Yield 2.0 g (84.5%).

ω -Piperidino-4-aminoacetanilide was also prepared from ω -piperidino-4-nitroacetanilide by this method.

4. Preparation of hydrochlorides. The bases were dissolved in absolute ether, and dry hydrogen chloride in anhydrous alcohol (30% solution) was added in the calculated quantity with cooling. The precipitate was filtered quickly since most of the hydrochlorides are hygroscopic, washed with absolute ether, dried in a cupboard or vacuum desiccator, and recrystallized.

5. Preparation of methiodides. The bases were dissolved in anhydrous acetone, methyl iodide was added, and the mixture left overnight. Absolute ether was added; the resulting precipitate was filtered, washed with ether, dried, and recrystallized from methyl alcohol.

6. Potentiometric titration. 0.8 millimole of the amine hydrochloride was dissolved in 80 ml freshly boiled, double-distilled water and titrated at 20° with 0.05 N sodium hydroxide solution (free from carbonate) using glass and calomel electrodes. A lamp voltmeter (pH-meter) of the PL-5 type of the State Institute of Applied Chemistry was used for measurements of $e\ m\ f$. The glass electrode was calibrated in the usual manner against standard buffer solutions. In cases where the solubility of the free amine base made it possible, the constant was calculated with reference to the pH at the semiequivalent point. In the remaining cases use was made of the general formula:

$$pK_a = pH + \lg A + \lg f_{AmH^+},$$

where A is the ratio of the concentration of amine salt to the concentration of its base, f_{AmH^+} is the activity coefficient of the ions of amine salt.

Since the ionic strength of the solution was about 0.01 N, it could be assumed that $\log f_{AmH^+}$ was approximately equal to -0.05 (from Shmidler's approximation formula [7]). The pK_a for each amine was calculated at not less than three points (with different values of ratio A) without allowing for the semiequivalence point.

SUMMARY

1. A series of arylamides of dialkylaminoacetic acids was synthesized. Their hydrochlorides were prepared, as well as the methiodides which had not been described in the literature.

2. The dissociation constants of these compounds were determined and compared with their pharmacological activity.

3. No direct relation between basicity and pharmacological activity could be detected in this series.

4. The basicity of arylamides of piperidinoacetic acid was found to be lower than the basicity of the corresponding arylamides of diethylaminoacetic acids, in spite of the fact that piperidine is a stronger base than diethylamine.

5. Xicaine^{*} and isoxicaine^{**} (No. 5 and 4, Table 2) were handed over for extensive clinical trials.

LITERATURE CITED

- [1] A. I. Remizov and N. V. Khromov-Borisov, J. Gen. Chem. 27, 1471 (1956);^{***} Z. I. Vedeneva, Pharm. and Toxicol. 19, no. 6, 3 (1956).
- [2] H. Erdtman and N. Löfgren, Svensk. kem. Tidskr. 49, 163 (1937).
- [3] N. Löfgren and B. Lungvist, Svensk. kem. Tidskr. 58, 206 (1946).
- [4] N. Löfgren, Arkiv. kem., Mineral., Geol., 22A, No. 18 (1946).
- [5] N. Löfgren and J. Fischer, Svensk. kem. Tidskr., 58, 219 (1946).
- [6] N. Löfgren, Studies on local anesthetics, Stockholm (1948).
- [7] T. D. Schmidler, J. Phys. Chem., 38, 533 (1934).
- [8] D. Balcom and A. Furst, J. Am. Chem. Soc. 75, 4334 (1953).
- [9] Handbook of Chemistry [in Russian] (State Chemical Press, 1952), Vol. III, p. 509.
- [10] P. E. Motovilov, Yearbook of the Institute of Experimental Medicine of the Academy of Medical Sciences of the USSR for 1956, p. 329; P. E. Motovilov, Pharm. and Toxicol. 21, no. 2, 40 (1958).^{***}

Received March 12, 1958

^{*} Ksikain in Russian original.

^{**} Isoksikain in Russian original.

^{***} Original Russian pagination. See C.B. Translation.

SALTS OF ALKYL CARBONIC ACIDS. IV.

V. I. Kurov

Leningrad State University and Leningrad Textile Institute

Lithium Alkyl Carbonates

Lithium alkyl carbonates are of great scientific interest. The acid lithium salts (bicarbonates) are unknown [1], but we have prepared the substituted acid salts LiRCO_2 in the crystalline form.

Lithium methyl carbonate CH_3OCOOLi could not be obtained by the method described for sodium alkyl carbonates and potassium alkyl carbonates [2]. We were the first to prepare this salt in 1948 at elevated temperature in an autoclave under pressure. A simpler method of preparation was subsequently devised [3]. To 300 ml anhydrous methanol was added 2 g lithium, and into the resultant solution of lithium methoxide was passed carbon dioxide for 3-4 hr at a rate of 20-30 ml, at the start with cooling to -8° and at the end of the experiment at room temperature. The resulting lithium methyl carbonate differed from the sodium and potassium salt in being completely soluble in methanol. Passage of carbon dioxide into a solution of the alkoxide in methanol-ether (1 : 1) therefore did not lead to deposition of the salt. The latter was brought down by treatment of the solution with four times the quantity of ether. Three-quarters of the volume of the solution of lithium methyl carbonate was diluted with 800 ml ether. A crystalline precipitate came down which was filtered through a Schott funnel and washed with ether. Yield of lithium methyl carbonate 6.2 g (product I). Further treatment of the filtrate with ether led to deposition of a further 1.9 g of the salt ("secondary" product). From the residual one-quarter of the solution a further 2.1 g was obtained after distillation of the methanol in a low vacuum at $15-18^\circ$. This crop of lithium methyl carbonate adhered to the walls of the flask (product II).

Found %: Li 8.45, 8.52 (product I); 8.61, 8.62 (product II); 8.65, 8.75 ("secondary" product).
 $\text{C}_2\text{H}_5\text{O}_2\text{Li}$. Calculated %: Li 8.47.

Product I. Found %: C 28.67, 29.43; H 3.64, 3.72. $\text{C}_2\text{H}_5\text{O}_2\text{Li}$. Calculated %: C 29.30; H 3.69.

The salt melted with decomposition at $198-200^\circ$. This test was carried out on product I.

Lithium propyl carbonate $\text{C}_3\text{H}_7\text{OCOOLi}$ and lithium butyl carbonate $\text{C}_4\text{H}_9\text{OCOOLi}$ [m. p. $212-214^\circ$ (with decom.)] were isolated by precipitation with absolute ether from their solutions in the respective alcohols. Solutions of the salts were prepared by passage of carbon dioxide into lithium propoxide and lithium butoxide respectively.

Found %: Li 6.17, 6.20; C 43.02, 43.37; H 6.68, 6.58. $\text{C}_4\text{H}_7\text{O}_2\text{Li}$. Calculated %: Li 6.31; C 43.66; H 6.41.

Found %: Li 5.68, 5.70; C 47.69, 47.79; H 7.35, 7.37. $\text{C}_5\text{H}_9\text{O}_2\text{Li}$. Calculated %: Li 5.59; C 48.48; H 7.31.

Great difficulties were associated with the determination of the lithium content of the salts of propyl and butyl carbonic acids by the sulfate method. Treatment of the weighed samples of the salt with sulfuric acid had to be repeated several times. The period required for the analysis was shortened by first converting the salts to nitrates by addition to the weighed samples of the salts of a few drops of water and concentrated nitric acid. The solution was evaporated to dryness, and then the nitrate was converted to sulfate with sulfuric acid.

Later a volumetric method was devised for the analysis of metal alkyl carbonates for metal content. This involved back titration with sodium hydroxide of the excess of hydrochloric acid taken for dissolution of a weighed sample of the alkyl carbonate. The volumetric method is speedier than the sulfate method and is not inferior in accuracy [4].

Lithium alkyl carbonates are white crystalline substances, more soluble in cold water than in hot. Their aqueous solutions have an alkaline reaction due to hydrolysis.

Rubidium Alkyl Carbonates

Rubidium methyl carbonate CH_3OCOORb was prepared by the method used for the preparation of lithium methyl carbonate. Its preparation was complicated by the inflaming of rubidium in the air and its extraordinarily rapid reaction with methanol even when strongly cooled. A further complication is that the rubidium is carried to the surface of the methanol by bubbles of evolved hydrogen and there enters into vigorous reaction. Measures had therefore to be taken to prevent the rubidium rising to the surface. 3.9 g rubidium was added in small pieces to 100 ml methanol cooled to -50 to -60° in a broad test tube stood in a Dewar flask containing a mixture of denatured alcohol and solid carbon dioxide. Carbon dioxide was passed through the resultant slightly cloudy solution for 5 hr at -15 to -20° .

After the mixture had been shaken, crystalline rubidium methyl carbonate came down. It was settled and filtered on a Schott funnel and washed with ether. Analysis revealed that the salt was not quite pure. It was therefore dissolved in a small quantity of methanol and again brought down with ether. Rubidium methyl carbonate can also be separated from solution by driving off the methanol in vacuum at low temperature.

Found % Rb 53.13, 53.33. $\text{C}_2\text{H}_5\text{O}_2\text{Rb}$. Calculated % Rb 53.25.

Rubidium methyl carbonate is extremely hygroscopic. It gives a strongly alkaline reaction in aqueous solution due to hydrolysis. The salt melts at $137-138^\circ$ (with decomp.).

Thermal Decomposition of Metal Alkyl Carbonates

Experiments were carried out to establish the relation between temperature and degree of decomposition of the salts. For this purpose the percent loss in weight of the salts at various temperatures was determined after 2-hours' heating. A correlation of weight loss with time of heating at constant temperature was also found for some of the salts. Results of experiments with potassium alkyl carbonates [5] are presented in Fig. 1 and 2. On the basis of these curves, temperatures at which thermal decomposition took place were selected. Results are set forth in Table 1 (experiments 1 to 4), and the analyses of the gaseous products in Table 2 (experiments 1-4).

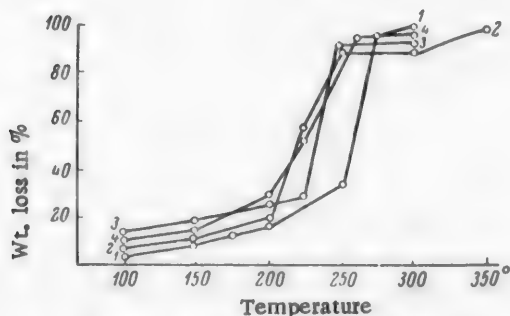


Fig. 1. Weight loss of volatile portion of potassium alkyl carbonates as a function of the temperature. 1) CH_3COOK , 2) $\text{C}_2\text{H}_5\text{COOK}$, 3) $\text{C}_3\text{H}_7\text{COOK}$, 4) $\text{C}_4\text{H}_9\text{COOK}$.

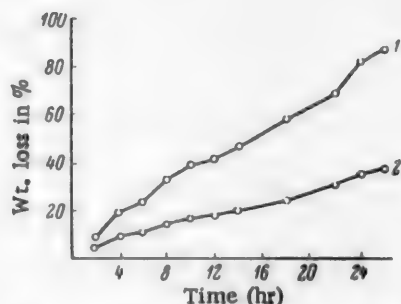


Fig. 2. Weight loss of potassium methyl carbonates as a function of time of heating at 175° ; 1) volatile portion, 2) original salt.

The liquid products of decomposition of potassium alkyl carbonates gave a positive reaction for aldehyde. The main bulk of the liquid resulting from decomposition of CH_3COOK distilled over at $64.5-65^\circ$.

TABLE 1

Decomposition of Potassium, Lithium and Rubidium Alkyl Carbonates

Expt. No.	Alkylcarbonate	Wt. of salt (in g)	Period of decomposition (in min.)	Decomposition temperature	Obtained			
					gas		liquid	solid residue
					ml	g	ml	g
1	CH ₃ COOK *	5.7	95	260-280°	520	0.73	0.73	4.15
2	C ₂ H ₅ COOK	3.2	50	245-275	185	0.41	0.82	2.00
3	C ₃ H ₇ COOK	7.1	150	220-225	415	0.72	2.27	4.12
4	C ₄ H ₉ COOK	3.9	120	230-260	311	0.56	1.49	1.87
5	CH ₃ COOLi	4.1	100	235-250	629	1.45	0.35	2.00
5a	CH ₃ COOLi	1.5	85	200-225	237	0.46	0.11	0.88
6	C ₂ H ₅ COOLi	5.5	75	220-250	187	0.30	2.00	2.00
7	C ₄ H ₉ COOLi **	3.1	115	210-220	110	0.18	0.54	0.74
8	CH ₃ COORb	4.02	80	235-255	262	0.42	0.55	3.03
8a	CH ₃ COORb	4.02	100	240-280	297	0.44	0.51	3.17
9	C ₄ H ₉ COORb	5.07	75	225-230	264	0.50	1.35	3.23

* A small quantity of CH₃COOK remained undecomposed.

** Great difficulties are associated with the procedure for decomposition of lithium butyl carbonate, so that quantitative accuracy is not claimed for the results.

that from C₃H₇COOK at 98.5°, and that from C₄H₉COOK at 116-118°. The liquid resulting from decomposition of C₂H₅COOK had n_D²⁰ 1.364.

Potassium content in the solid residue found (in %): for CH₃COOK 53.63, for C₂H₅COOK 49.83, for C₃H₇COOK 48.32, for C₄H₉COOK 48.67. Losses on ignition of the residue to constant weight (for removal of resins) were respectively (in %): 5.12, 11.4, 14.7 and 14.3.

Found %: K 56.38, 56.50, 56.63, 55.97. K₂CO₃. Calculated %: K 56.58.

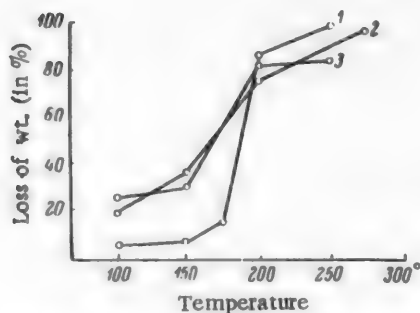


Fig. 3. Weight loss of volatile portion of lithium alkyl carbonates as a function of the temperature. 1) CH₃COOLi, 2) C₂H₅COOLi, 3) C₄H₉COOLi.

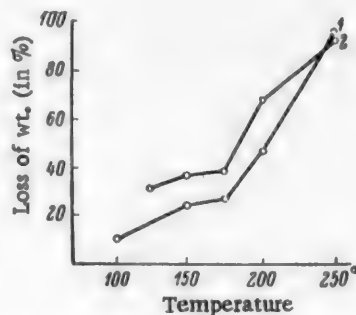


Fig. 4. Weight loss of volatile portion of rubidium alkyl carbonates as a function of the temperature. 1) CH₃COORb, 2) C₄H₉COORb.

The potassium carbonate formed on decomposition of potassium alkyl carbonates is a more active polymerizing agent than sodium carbonate, due to which the solid residues from the decomposition of the potassium salts are more darkly colored (coffee colored).

The curves of weight loss of the volatile portion of lithium alkyl carbonates versus temperature (thermal decomposition at various temperatures) are plotted in Fig. 3. Results of the thermal decomposition are presented

in Table 1 (expts. 5-7); analyses of the gaseous products are set forth in Table 2 (expts. 5-7). The liquids resulting from decomposition of CH_3OCOOLi , $\text{C}_2\text{H}_5\text{OCOOLi}$ and $\text{C}_4\text{H}_9\text{OCOOLi}$ had, respectively, n_D^{20} 1.331, 1.389 and 1.402. •

The lithium content of the solid residues from decomposition of CH_3OCOOLi , $\text{C}_2\text{H}_5\text{OCOOLi}$ and $\text{C}_4\text{H}_9\text{OCOOLi}$ was, respectively, 16.53, 15.97 and 15.44%. Losses on ignition (%) were: 16.0, 12.0 and 19.0. In the ignited residues (after removal of resinous impurities) were found, respectively, (in %): Li 18.64, 18.94, 18.88. Li_2CO_3 calculated % Li 18.79.

Data for the thermal stability and thermal decomposition of rubidium alkyl carbonates are presented in Fig. 4 and Tables 1 and 2.

The liquid obtained by decomposition of CH_3OCOORb had n_D^{20} 1.3292; that obtained by decomposition of $\text{C}_4\text{H}_9\text{OCOORb}$ had n_D^{20} 1.4022.

The solid residue from decomposition of CH_3OCOORb had Rb 71.05%. Loss on ignition 4.4%. The ignited residue had % Rb 74.37. Rb_2CO_3 calcd. % Rb 74.02.

We see on inspection of Fig. 1 that the thermal stability of potassium methyl carbonate is higher than that of the other potassium alkyl carbonates.

We see from Table 2 that the gaseous products of decomposition of potassium alkyl carbonates have the same composition as the products of decomposition of sodium alkyl carbonates. The mechanisms of thermal decomposition of the two groups of salts therefore appear to be similar.

TABLE 2
Gas Analysis

Expt. No.	Metal alkyl carbonate	Content in gas (in %)			
		CO_2	C_nH_{2n}	CO	H
1	CH_3OCOOK	23.0	6.3	70.7	—
2	$\text{C}_2\text{H}_5\text{OCOOK}$	61.6	5.9	32.5	—
3	$\text{C}_3\text{H}_7\text{OCOOK}$	67.2	1.8	31.0	—
4	$\text{C}_4\text{H}_9\text{OCOOK}$	79.0	2.3	16.8	1.9
5	CH_3OCOOLi	97.2	2.8	—	—
5a	CH_3OCOOLi	97.0	3.0	—	—
6	$\text{C}_2\text{H}_5\text{OCOOLi}$	56.2	3.6	36.1	4.1
7	$\text{C}_4\text{H}_9\text{OCOOLi}$	43.0	11.2	45.2	0.6
8	CH_3OCOORb	35.7	—	64.3	—
8a	CH_3OCOORb	35.2	1.0	63.8	—
9	$\text{C}_4\text{H}_9\text{OCOORb}$	94.2	1.2	4.0	0.6

We see from consideration of the curves of Fig. 2 that the thermal stability of lithium methyl carbonate is greater than that of lithium propyl and butyl carbonates. Lithium alkyl carbonates have a lower thermal stability than sodium and potassium alkyl carbonates.

The thermal stability of rubidium alkyl carbonates is low. This is especially true of rubidium butyl carbonate (Fig. 4).

In the light of the foregoing facts we may suggest that the mechanism of thermal breakdown of potassium alkyl carbonates, and of most lithium alkyl carbonates and rubidium alkyl carbonates is similar to that of the breakdown of sodium alkyl carbonates [2]. Carbon monoxide can be formed from the carbon of the carbonate group. We confirmed this with the help of radioactive C^{14} in a study of the thermal decomposition of sodium ethyl and methyl carbonates containing C^{14} in the carbonate group [6].

• The literature [7] reports n_D^{20} : CH_3OH 1.3288, $\text{C}_2\text{H}_5\text{OH}$ 1.3610, $n\text{-C}_3\text{H}_7\text{OH}$ 1.3854, $n\text{-C}_4\text{H}_9\text{OH}$ 1.3991.

SUMMARY

1. The following alkyl carbonates were prepared for the first time: lithium methyl carbonate CH_3LiCO_3 , lithium propyl carbonate $\text{C}_3\text{H}_7\text{LiCO}_3$, lithium butyl carbonate $\text{C}_4\text{H}_9\text{LiCO}_3$, and rubidium methyl carbonate CH_3RbCO_3 .

2. The thermal stability of potassium, lithium and rubidium alkyl carbonates is found to depend on the metal and radical entering into the composition of the salt.

3. Potassium, lithium and rubidium alkyl carbonates were subjected to thermal decomposition, and a general mechanism of decomposition was advanced.

LITERATURE CITED

- [1] B. V. Nekrasov, Course of General Chemistry [in Russian] (State Chem. Press, 1952), p. 674.
- [2] V. I. Kurov, J. Gen. Chem., 21, 490 (1951).*
- [3] V. I. Kurov, Trans. Leningrad Textile Inst., No. 6, 99 (1955).
- [4] V. I. Kurov, Herald (Vestnik) of Leningrad State Univ., No. 10, 139 (1958).
- [5] V. I. Kurov, J. Gen. Chem. 21, 1637 (1951).*
- [6] V. I. Kurov, J. Gen. Chem. 27, 1754 (1957).*
- [7] Handbook of Chemistry, II [in Russian] (State Chem. Press, 1951), p. 1035, 1037, 1039.

Received October 4, 1957

*Original Russian pagination. See C.B. Translation.

ESTERS OF N-ARYLTHIOCARBAMIDE-N'-PHOSPHORIC ACIDS

E. S. Levchenko and I. É. Sheinkman

Institute of Organic Chemistry of the Ukrainian SSR, Academy of Sciences

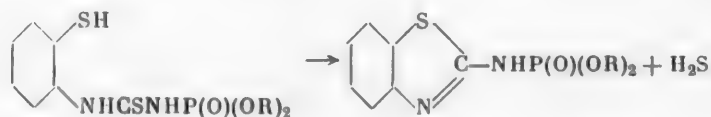
As was reported earlier [1], esters of isothiocyanatophosphoric acid react with amines, aniline in particular, to form derivatives of thiocarbamide.



On testing the physiological properties of these compounds it was found that one of them, namely the diethyl ester of N-phenylthiocarbamide-N'-phosphoric acid, $(C_2H_5O)_2P(O)NHCSNHC_6H_5$, has insecticidal and tuberculostatic properties. Therefore, it was of interest to prepare a series of esters of N-arylthiocarbamide-N'-phosphoric acids with various substituents in the aromatic nucleus and to test their physiological properties.

Diethyl isothiocyanatophosphate [1] was caused to react with p- and o-toluidines, p- and o-anisidines, p-phenetidine, o-, m-, and p-chloroanilines, m-aminophenol, p-fluoroaniline, p-aminobenzenesulfonamide, sodium p-aminosalicylate, and phenylhydrazine. The diethyl esters of N-arylthiocarbamide-N'-phosphoric acids thereby obtained are colorless, crystalline substances having acid properties. They are readily soluble in alkali and soda solutions and are precipitated unchanged from alkaline solutions by acid. Most of the compounds obtained crystallize from alcohol or acetone and are slightly soluble in water, benzene, ether, carbon tetrachloride, and petroleum ether.

Diethyl and diphenyl isothiocyanatophosphates and diphenyl isothiocyanatothiophosphate also form analogous thiocarbamide derivatives with o-aminothiophenol. However, these compounds are unstable, and on prolonged standing or on heating evolve hydrogen sulfide and cyclize, forming the corresponding derivatives of benzothiazole.



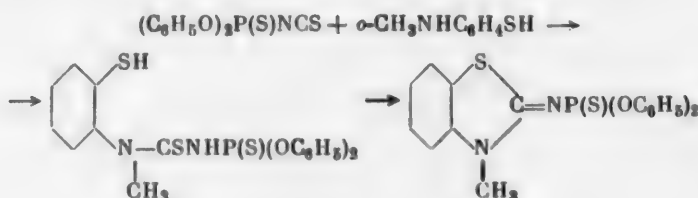
Hoffmann [2], on heating N-phenyl-N'-o-mercaptophenylthiocarbamide, observed analogous cyclization.

In the reaction of o-aminothiophenol with diisobutyl isothiocyanatophosphate, the corresponding thiocarbamide derivative could not be obtained; even at room temperature the reaction product evolves hydrogen sulfide and cyclizes to diisobutyl N-(benzothiazolyl-2)phosphamate.

Diethyl N-(benzothiazolyl-2)phosphamate is a liquid which does not distill without decomposition and is readily soluble in organic solvents (alcohol, ether, benzene), difficultly soluble in water, and readily soluble in alkali and soda solutions and in concentrated hydrochloric acid. When the hydrochloric acid solution is diluted with water, the salt formed is hydrolyzed. Diethyl N-(benzothiazolyl-2)phosphamate gives a well-crystallized picrate.

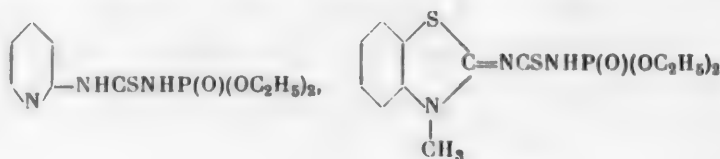
Diphenyl N-(benzothiazolyl-2)phosphamate, diisobutyl N-(benzothiazolyl-2)phosphamate, and diphenyl N-(benzothiazolyl-2)thiophosphamate are colorless, crystalline compounds. They are readily soluble in alkali and soda solutions but are insoluble in hydrochloric acid.

N-Methyl-o-aminothiophenol also reacts readily with esters of isothiocyanatothiophosphoric acid. Undoubtedly, the first reaction product is the corresponding thiocarbamide derivative, but it cannot be isolated since, even at room temperature, cyclization occurs with splitting-off of hydrogen sulfide, and 3-methylbenzothiazolidene-2 derivatives are formed. Diphenyl isothiocyanatophosphate and N-methyl-o-aminothiophenol give diphenyl N-(3-methylbenzothiazolidene-2)thiophosphamate according to the scheme:

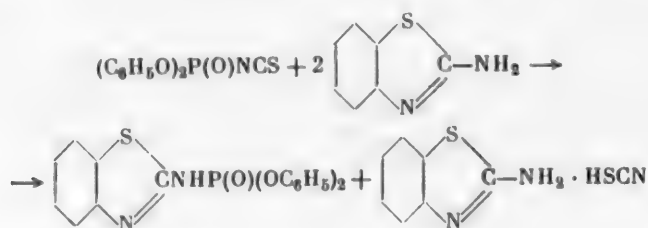


This substance does not have acid properties and is not soluble in alkalis.

α -Aminopyridine and N-methylbenzothiazoloneimine react with diethyliothiocyanatothiophosphate to give the corresponding thiocarbamide derivatives, which are colorless, crystalline substances, amphoteric in character.



The diethyl ester of N-(3-methylbenzothiazolidene-2)thiocarbamide-N'-phosphoric acid forms a yellow solution in alcohol. On reaction of diphenyl isothiocyanatophosphate with 2-aminobenzothiazole, diphenyl N-(benzothiazolyl-2)phosphamate is obtained according to the scheme:



In the given case the isothiocyanate group acts like a halogen. Michalski and Wieczorkowski [3] observed a similar phenomenon in the reaction of diethyl isothiocyanatophosphate with dimethylamine.

Diphenyl N-(benzothiazolyl-2)phosphamate was identified thru a mixture test with the substance obtained on cyclization of the diphenyl ester of N-(o-mercaptophenyl)thiocarbamide-N'-phosphoric acid.

Esters of arylthiocarbamidephosphoric acids were tested as insecticides (G. A. Efimov, Laboratory of Insecticide Chemistry of the IOKh,* Acad. Sci. Ukr. SSR) and as tuberculostatic substances (T. S. Ginsburg, Ukrainian Scientific Research Institute of Tuberculosis). They all proved to be weak insecticides and nearly inactive tuberculostatic substances, with the exception of the diethyl ether of N-(p-chlorophenyl)thiocarbamide-N'-phosphoric acid, which excels DDT in its contact insecticidal effect, and the diethyl ester of N-phenylthiocarbamide-N'-phosphoric acid, which proved to be an active tuberculostatic substance.

EXPERIMENTAL

Esters of N-arylthiocarbamide-N'-phosphoric acids. To an ethereal solution of 0.01 mole of the isothiocyanatophosphoric acid ester, an ethereal solution of an equimolar quantity of the amine was slowly added

*Institute of Organic Chemistry.

dropwise. The reaction mixture was left to stand for several hours at room temperature. The reaction products, which separated from the reaction mixture in the form of a crystalline precipitate, was filtered out by suction and recrystallized. If the product obtained did not separate from solution as a solid precipitate, the reaction mixture was treated with 1 N sodium hydroxide solution, and the aqueous-alkaline layer was drawn off and acidified. The product which precipitated in this case was filtered out by suction and purified. The diethyl esters of N-arythiocarbamide-N'-phosphoric acids and their yields, melting points, and analytical data are given in the table.

Diethyl Esters of the General Formula $(C_2H_5O)_2P(O)NHC(S)NHR$

No.	R	Melting poing	Yield (in %)	Empirical formula	% N	
					found	calc.
1	<i>o</i> -CH ₃ C ₆ H ₄	132—133°	64.7	C ₁₂ H ₁₀ O ₃ N ₂ SP	9.36, 9.45	9.27
2	<i>p</i> -CH ₃ C ₆ H ₄	117—118	53.6	C ₁₂ H ₁₀ O ₃ N ₂ SP	9.28, 9.11	9.27
3	<i>o</i> -CH ₃ OC ₆ H ₄	129—130	83.2	C ₁₂ H ₁₀ O ₄ N ₂ SP	8.94, 8.92	8.80
4	<i>p</i> -CH ₃ OC ₆ H ₄	112—113	55.4	C ₁₂ H ₁₀ O ₄ N ₂ SP	8.85, 8.74	8.80
5	<i>o</i> -ClC ₆ H ₄	126—127	47.0	C ₁₁ H ₁₀ O ₃ N ₂ ClSP	8.81, 8.83	8.68
6	<i>m</i> -ClC ₆ H ₄	109—110	42.0	C ₁₁ H ₁₀ O ₃ N ₂ ClSP	8.44, 8.51	8.68
7	<i>p</i> -ClC ₆ H ₄	121—122	74.3	C ₁₁ H ₁₀ O ₃ N ₂ ClSP	8.93, 8.82	8.68
8	<i>p</i> -FC ₆ H ₄	133—134	48.6	C ₁₁ H ₁₀ O ₃ N ₂ FSP	9.22, 9.48	9.15
9	<i>p</i> -C ₂ H ₅ OC ₆ H ₄	130—131	57.3	C ₁₃ H ₂₁ O ₄ N ₂ SP	8.39, 8.38	8.43
10	<i>m</i> -HOC ₆ H ₄	118—120	41.8	C ₁₁ H ₁₇ O ₄ N ₂ SP	9.02, 8.97	9.21
11	<i>p</i> -H ₂ NSO ₂ C ₆ H ₄	131—132	45.0	C ₁₁ H ₁₈ O ₅ N ₂ S ₂ P	11.45, 11.48	11.44
12	<i>o</i> -HSC ₆ H ₄	108—110 (dec.)	99.0	C ₁₁ H ₁₇ O ₃ N ₂ S ₂ P	8.88, 8.74	8.75
13	3(OH)4(COONa)C ₆ H ₃	130—131 (dec.)	70.3	C ₁₂ H ₁₆ O ₆ N ₂ SPNa	7.88, 7.96	7.56

Note. Compounds 1-9 and 11 were crystallized from alcohol, and 10 and 12 from benzene; 13 was purified thru reprecipitation from methanolic solution by ether.

Diethyl ester of N-(phenylamino)thiocarbamide-N'-phosphoric acid, yield 25.6%, prisms (from alcohol), m. p. 124—125°.

Found %: N 13.74, 13.65. C₁₁H₁₄O₃N₂SP. Calculated %: N 13.86.

Diphenyl ester of N-(*o*-mercaptophenyl)thiocarbamide-N'-phosphoric acid, yield 90.4%, colorless crystals (from benzene), dec. 113—115°.

Found %: N 6.55, 6.51. C₁₉H₁₇O₃N₂S₂P. Calculated %: N 6.73.

Diphenyl ester of N-(*o*-mercaptophenyl)thiocarbamide-N'-thiophosphoric acid, yield 77%, needles (from alcohol) dec. 110—111°.

Found %: N 6.47, 6.61. C₁₉H₁₇O₂S₃P. Calculated %: N 6.48.

Diphenyl N-(benzothiazolyl-2)phosphamate. A 0.01 mole quantity of the diphenyl ester of N-(*o*-mercaptophenyl)thiocarbamide-N'-phosphoric acid was heated in an oil bath at 120—125°. In this case the substance melted and evolved hydrogen sulfide, and the melt solidified. On cooling, the substance was pulverized and washed with ether. Yield 90%, needles (from alcohol), m. p. 153—154°.

Found %: N 7.35, 7.46. C₁₉H₁₅O₃N₂SP. Calculated %: N 7.33.

Picrate of diethyl N-(benzothiazolyl-2)phosphamate. A 0.01 mole quantity of the diethyl ester of N-(*o*-mercaptophenyl)thiocarbamide-N'-phosphoric acid was heated in an oil bath at 110—115° until the evolution of hydrogen sulfide ceased. The reaction product, an oil which did not crystallize, was dissolved in methyl alcohol; to the solution was added a solution of picric acid in methyl alcohol, and the resulting crystalline precipitate of the picrate was filtered out by suction. Yield 87%, needles (from methyl alcohol), m. p. 158—161°.

Found %: N 13.37, 13.30. C₁₇H₁₈O₁₀H₅SP. Calculated %: N 13.59.

Diphenyl N-(Benzothiazolyl-2)thiophosphamate was prepared by heating the diphenyl ester of N-(o-mercaptophenyl)thiocarbamide-N'-thiophosphoric acid to 120°. Yield 94.5%, leaflets (from alcohol), m. p. 154-155°.

Found %: N 6.96, 6.81. $C_{19}H_{15}O_2N_2S_2P$. Calculated %: N 7.03.

Diisobutyl N-(benzothiazolyl-2)phosphamate. To an ethereal solution of 0.01 mole of diisobutyl isothiocyanatophosphate was added an ethereal solution of 0.01 mole of o-aminothiophenol. The evolution of hydrogen sulfide soon began, and a crystalline precipitate separated from the solution. After two days the substance was filtered out by suction and washed with ether. Yield 73%, prisms (from petroleum ether), m. p. 119-120°.

Found %: N 8.59, 8.45. $C_{15}H_{23}O_2N_2SP$. Calculated %: N 8.18.

Diphenyl N-(3-methylbenzothiazolidene-2)thiophosphamate. Ethereal solutions of equimolar quantities of diphenyl isothiocyanatophosphate and N-methyl-o-aminothiophenol were mixed together and the mixture left for two days. Hydrogen sulfide was evolved from the solution, and the reaction product separated as a crystalline precipitate, which was filtered out by suction and washed with ether. Yield 58%, prisms (from alcohol), m. p. 147-149°.

Found %: N 6.88, 6.81. $C_{20}H_{17}O_2N_2S_2P$. Calculated %: N 6.79.

Diethyl ester of N-(α -pyridyl)thiocarbamide-N'-phosphoric acid. Ethereal solutions of equimolar quantities of α -aminopyridine and diethyl isothiocyanatophosphate were mixed together. In this case an oily liquid separated out which crystallized after a certain time. Yield 90%, colorless crystals (from alcohol), m. p. 133-134°.

Found %: N 14.30, 14.39. $C_{16}H_{18}O_2N_2SP$. Calculated %: N 14.52.

Diethyl ester of N-(3-methylbenzothiazolidene-2)thiocarbamide-N'-phosphoric acid. The compound was prepared, similarly to the preceding, from 3-methyl-2-benzothiazoloneimine and diethyl isothiocyanatophosphate. The reaction product separated from solution in the crystalline state. Yield 76.5%, colorless crystals (from alcohol), m. p. 152-153°.

Found %: N 11.57, 11.62. $C_{15}H_{18}O_2N_2S_2P$. Calculated %: N 11.69.

Reaction of 2-aminobenzothiazole with diphenyl isothiocyanatophosphate. To an ethereal solution of 0.005 mole of diphenyl isothiocyanatophosphate, a solution of 0.01 mole of 2-aminobenzothiazole was slowly added dropwise. In this case a mixture of diphenyl N-(benzothiazolyl-2)phosphamate and 2-aminobenzothiazole thiocyanate precipitated from the solution. The mixture of the two substances was filtered out by suction (2.15 g) and treated with water. In this case the thiocyanate dissolved, whereas the diphenyl N-(benzothiazolyl-2)phosphamate remained in the precipitate (1.37 g, 70.6%). Needles with m. p. 153-154° after crystallization from alcohol. The compound was identified thru a mixed melting-point test. The aqueous thiocyanate solution was evaporated in vacuo, and the dry residue (0.7 g) was crystallized from a small amount of water. Colorless crystals with m. p. 136-137°.

Found %: N 20.10, 19.91. $C_{18}H_{12}N_4S_2$. Calculated %: N 20.07.

2-Aminobenzothiazole thiocyanate was readily soluble in alcohol and water and insoluble in benzene and ether; on treatment of the solution with alkali it was converted to free 2-aminobenzothiazole.

Reaction of diethyl isothiocyanatophosphate with 2-aminobenzothiazole. When ethereal solutions of 0.01 mole of diethyl isothiocyanatophosphate and 0.02 mole of 2-aminobenzothiazole were mixed together, 2-aminobenzothiazole thiocyanate separated in the form of a crystalline precipitate, which was filtered out by suction and washed with ether. Yield 98.0%, m. p. 136-137°. The compound did not give any melting-point depression with the 2-aminobenzothiazole thiocyanate obtained in the preceding experiment.

SUMMARY

1. The reaction of esters of isothiocyanatophosphoric acid with aromatic and heterocyclic amines has been studied.

2. It has been shown that the products of reaction of esters of isothiocyantophosphoric acid with o-aminothiophenol can cyclize to form benzothiazole derivatives.

3. Certain esters of N-arylthiocarbamide-N'-phosphoric acids have insecticidal activity and tuberculo-static properties.

LITERATURE CITED

- [1] E. S. Levchenko and L. N. Zhmurova, Ukr. Chem. J. 22, 623 (1956).
- [2] A. W. Hoffmann, Ber., 20, 1796 (1887).
- [3] J. Michalski and J. Wleczorkowski, Roczn. chem. 31, 585 (1957).

Received January 6, 1958

ORGANOBORON COMPOUNDS

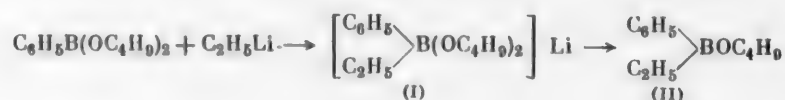
XXXIV.* ALKYLPHENYLBORON CHLORIDES

B. M. Mikhailov and P. M. Aronovich

Institute of Organic Chemistry of the USSR, Academy of Sciences

Isobutyl propylphenyl- and butylphenylborinates [1] were prepared by us earlier by treating isobutyl phenylboronate with lithium alkyls. Simultaneously an article by Torssell [2] was published, containing a description of the synthesis of propyl methylphenylborinate and butyl ethylphenylborinate by means of Grignard reagents.

We continued the work on the synthesis of organoboron compounds of the aliphatic-aromatic series and prepared isobutyl ethylphenylborinate (II) by treating isobutyl phenylboronate with ethyllithium.



It was found that the lithium ethylphenyldiisobutoxyborate (I) formed in the first stage of the synthesis could be decomposed not only by hydrogen chloride, but also by dilute hydrochloric acid. The same simplification can also be introduced in the procedure for the preparation of esters of propylphenyl- and butylphenylborinic acids, since lithium alkylphenyldiisobutoxyborates, in contrast to lithium diphenyldiisobutoxyborate [3], decomposed only in one direction on treatment with dilute hydrochloric acid, esters of alkylphenylborinic acids being formed.

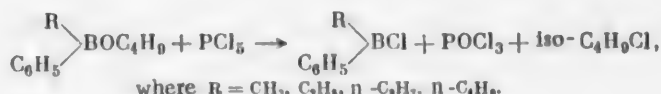
On treatment of the phenylboronic acid esters with methyllithium, isobutyl methylphenylborinate can be obtained only in negligible yield. A gaseous substance, which catches fire in air (probably trimethylboron), is formed in the reaction, and about 60% of the original ester remains unchanged. Therefore, the isobutyl methylphenylborinate needed for further work was prepared by treatment of isobutyl phenylboronate with methylmagnesium bromide.

Isobutyl alkylphenylborinates have the same stability toward hydrolysis as alkyl dialkyl- [4] and diarylborinates [5, 6]. They are readily soluble in aqueous alkali solutions and are precipitated from the solutions on acidification. Isobutyl alkylphenylborinates remain unchanged even on prolonged heating with dilute hydrochloric acid. On addition of 36% hydrochloric acid to isobutyl alkylphenylborinates, however, the liquids dissolve in one another. Different esters dissolve at different rates. Thus, isobutyl methylphenyl- and ethylphenylborinates mix instantly with concentrated hydrochloric acid with evolution of heat. It takes about 30 hours at room temperature to form a homogeneous liquid on mixing isobutyl propylphenylborinate and hydrochloric acid, whereas in the case of the butylphenylborinic acid ester, the process takes more than two days. On distillation of the solution obtained by mixing isobutyl ethylphenylborinate and hydrochloric acid in vacuo, only about 30% of the original ester could be recovered.

*For papers Nos. XXXI-XXXIII, see Bull. Acad. Sci. USSR, Div. Chem. Sci. 1959, 172, 356, 546.

The formation of homogeneous solutions on adding hydrochloric acid to isobutyl alkylphenylborinates (practically insoluble in water) is probably due to complex compounds which only partly decompose into their original components on heating.

On treatment with phosphorus pentachloride, alkylphenylborinic acid esters are converted to alkylphenylboron chlorides in 76-83% yields; similarly, diarylborinic and dialkylborinic acid esters form diarylboron chlorides [7] and dialkylboron chlorides [8], respectively, with PCl_5 . The reaction takes place according to the following equation:



Alkylphenylboron chlorides are colorless liquids with a sharp, disagreeable odor, which fume strongly in air; methylphenyl- and ethylphenylboron chlorides ignite spontaneously.

EXPERIMENTAL

All operations were performed in a dry nitrogen atmosphere.

Isobutyl methylphenylborinate. To a stirred mixture of 127 ml of isobutyl phenylboronate and 125 ml of ether at -60 to -70° the methylmagnesium bromide solution prepared from CH_3Br , 13.4 g of magnesium, and 300 ml of ether was added during 3-4 hours. The reaction mass was stirred for 4-5 hours at -70° , left in the cooling bath overnight, and decomposed on the next day with 150 ml of 20% hydrochloric acid. The ether was driven off from the upper layer, 50 ml of isobutyl alcohol was added to the residue, and the latter was distilled in vacuo. After removal of the isobutyl alcohol-water mixture, isobutyl methylphenylborinate distilled at $93\text{--}96^\circ$ (8 mm); the yield of ester was 61.8 g (71%). On redistillation, the isobutyl methylphenylborinate boiled at $88\text{--}89^\circ$ (7 mm), n_D^{20} 1.4862, d_4^{20} 0.8940.

Found %: C 74.96; H 9.64; B 6.34. $\text{C}_{11}\text{H}_{17}\text{OB}$. Calculated %: C 75.03; H 9.73; B 6.14.

A colorless liquid with a disagreeable odor; mixes with common organic solvents, insoluble in water, rapidly changes in air to phenylboronic acid.

Isobutyl ethylphenylborinate. To the ethyllithium solution prepared from 50 ml of ethyl bromide, 8 g of lithium, and 500 ml of ether, a mixture of 127 ml of isobutyl phenylboronate and 125 ml of ether was added during 30 minutes with stirring at -20 to -50° . The reaction mass was stirred for 3-4 hours at -70° , left overnight in the cooling mixture, and worked up as stated for the preparation of the methylphenylborinic acid ester. The yield of isobutyl ethylphenylborinate, b. p. $94\text{--}97^\circ$ (6 mm), was 65 g (68.5%). After redistillation b. p. $95\text{--}96^\circ$ (6 mm), n_D^{20} 1.4828, d_4^{20} 0.8923.

Found %: C 75.79; H 10.02; B 5.75. $\text{C}_{12}\text{H}_{19}\text{OB}$. Calculated %: C 75.81; H 10.07; B 5.69.

The properties of isobutyl ethylphenylborinate were similar to those of the methylphenylborinate, but the former had a stronger, more disagreeable odor. It disproportionated on prolonged heating at $95\text{--}100^\circ$.

Effect of hydrochloric acid on isobutyl alkylphenylborinates. To 0.02 mole of the isobutyl alkylphenylborinate was added 1.7 ml of 36.3% hydrochloric acid, and the mixture was shaken. In the case of the methyl- and ethylphenylborinates, formation of a homogeneous liquid with evolution of heat was observed. Mixtures of the propyl- and butylphenylborinates with hydrochloric acid rapidly became stratified. On standing at room temperature a mixture of the propylphenylborinate with hydrochloric acid changed to a homogeneous liquid within 30-35 hours, whereas a mixture of the butylphenylborinate with hydrochloric acid changed within 50-55 hours.

On distillation of the liquid obtained by mixing 11.8 g of isobutyl ethylphenylborinate with 5.3 ml of 36.3% hydrochloric acid, two fractions were collected. The first fraction (9.8 g), b. p. $26.5\text{--}27^\circ$ (17 mm), was a mixture of hydrochloric acid and isobutyl alcohol and contained 0.5% boron. The second fraction (3.8 g), b. p. $97\text{--}101^\circ$ (8 mm), was isobutyl ethylphenylborinate. Residue after distillation, 3.1 g.

Alkylphenylboron chlorides. Into a Favorskii flask was put 0.2 mole of the isobutyl alkylphenylborinate, and 37.5 g of PCl_5 was added during 40-50 minutes with shaking. Spontaneous warming occurred in the course of the reaction. The rate of addition of PCl_5 was regulated so as to keep the mixture temperature below 60-70°. When all the PCl_5 had been added, the contents of the flask were heated at 50-60° for 10-15 minutes, until the solid material was all gone, and distilled in vacuo. After driving off the isobutyl chloride and phosphorus oxychloride, the alkylphenylboron chloride was distilled and then purified by redistillation through a small column. The yields and characteristics of the alkylphenylboron chlorides obtained are given in the table. On slow distillation through a column methylphenylboron chloride partly decomposed. Even after many distillations propylphenylboron chloride contained an excessive amount of chlorine.

Alkylphenylboron Chlorides ($\text{C}_6\text{H}_5 > \text{BCl}$)

R	Yields (in %)	B. p. (pressure in mm)	d_4^{20}	Found (%)		Calculated (%)	
				Cl	H	Cl	H
CH_3	81.0	68-69° (24)	1.0440	25.73	8.0	25.62	7.82
C_2H_5	83.3	85-86 (20)	1.0328	23.37	7.05	23.25	7.10
$n\text{-C}_3\text{H}_7$	76.4	83-84 (9)	1.0274	22.43	6.40	21.30	6.50
$n\text{-C}_4\text{H}_9$	82.5	90-91 (7)	0.9966	19.80	6.01	19.65	6.00

SUMMARY

1. Isobutyl methylphenylborinate and ethylphenylborinate have been synthesized.
2. Methylphenyl-, ethylphenyl-, propylphenyl-, and butylphenylboron chlorides have been prepared by treatment of isobutyl alkylphenylborinates with phosphorus pentachloride.

LITERATURE CITED

- [1] B. M. Mikhailov and P. M. Aronovich, *Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1955, 946.*
- [2] K. Torssell, *Acta Chem. Scand.* 9, 245 (1955).
- [3] B. M. Mikhailov and P. M. Aronovich, *Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1956, 322.*
- [4] J. Johnson, H. Snyder, and M. G. van Campen, *J. Am. Chem. Soc.* 60, 119 (1938).
- [5] B. M. Mikhailov and V. A. Vaver, *Proc. Acad. Sci. USSR*, 102, 531 (1955).
- [6] B. M. Mikhailov and V. A. Vaver, *Bull. Acad. Sci. USSR, Div. Chem. Sci.* 1956, 451.*
- [7] B. M. Mikhailov and N. S. Fedotov, *Bull. Acad. Sci. USSR, Div. Chem. Sci.* 1956, 375.*
- [8] B. M. Mikhailov and T. A. Shchegoleva, *Bull. Acad. Sci. USSR, Div. Chem. Sci.* 1956, 508.*

Received February 24, 1958.

*Original Russian pagination. See C.B. Translation.

ORGANOBORON COMPOUNDS

XXXV. ALKYLPHENYLBORINIC ACIDS AND THEIR ANHYDRIDES

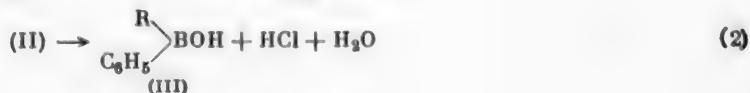
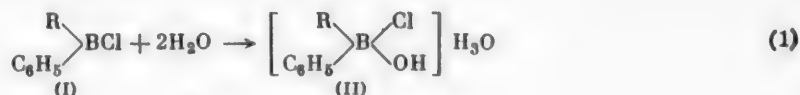
B. M. Mikhailov and P. M. Aronovich

Institute of Organic Chemistry of the USSR Academy of Sciences.

Alkylphenylborinic acids have not been described hitherto. The only reference to an instance — methylphenylborinic acid — appears in the work of Torrsell [1], who states that he obtained this acid through the hydrolysis of its propyl ester, but gives neither reaction conditions, nor constants, nor analytical data for the substance obtained.

As was stated earlier [2], we were unable to hydrolyze isobutyl alkylphenylborinates. Later, we attempted to prepare alkylphenylborinic acids by treatment of alkylphenylboron chlorides, the synthesis of which is described in the preceding paper [2], with water. In this case it was found that the nature of alkyl radical has a considerable effect on the behavior of alkylphenylboron chlorides toward water. When water reacts with ethylphenylboron chloride, instead of the expected ethylphenylborinic acid, ethylboronic acid is obtained; methylphenyl- and propylphenylboron chlorides form a mixture of the corresponding alkylphenylborinic and alkylboronic acids on hydrolysis, and only butylphenylboron chloride reacts normally with water to form butylphenylborinic acid. However, if a mixture of butylphenylboron chloride and water is left for a long time (6 days instead of 24 hours) at room temperature, partial hydrolysis of the boron-carbon bond occurs, and a small amount of butylboronic acid is obtained along with the butylphenylborinic acid.

The mechanism of hydrolysis of alkylphenylboron chlorides is obviously connected with processes of complex formation, characteristic of boron compounds. The alkylphenylboron chloride (I) probably adds at first to a water molecule to form a complex alkylphenylchlorohydroxyboric acid (II) which then splits off hydrogen chloride and is converted to an alkylphenylborinic acid (III). Along with this the complex boric acid (II) splits off benzene to form alkylboronic acid (IV).



Earlier we observed similar phenomena of decomposition of complex boric acids in two directions on treatment of lithium diphenyldiisobutoxyborate with hydrochloric acid, which resulted in the splitting off of an isobutoxyl, as well as a phenyl group from the complex anion [3]. The phenyl group, rather than the more electronegative isobutoxyl group, is also removed from the complex boric acid anion on treatment of the salts

of certain triarylisobutoxyboric acids with hydrogen chloride, as a result of which esters of diarylborinic acids, instead of the expected triarylboron compounds, are obtained [4].

The varying degree of conversion of alkylphenylboron chlorides to alkylboronic acids obviously depends on the ratio of the rates of reactions (2) and (3). The rate of reaction (3) decreases as the chain length of the alkyl radical increases, as is shown by the slower conversion of butylphenylboron chloride to butylboronic acid in comparison with the formation of ethylboronic acid from ethylphenylboron chloride. Some deviation from this regularity is observed in the case of the first member of the homologous series - methylphenylboron chloride, from which benzene is split off more slowly than from ethylphenylboron chloride.

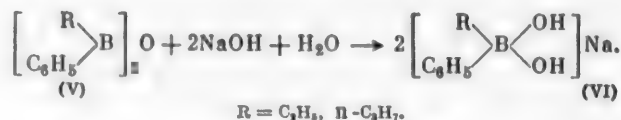
We observed a similar effect of the nature of the alkyl radical on treatment of isobutyl alkylphenylborinates with concentrated hydrochloric acid [2]. In this case lengthening the chain of the alkyl radical obviously caused a decrease in the rate of formation of the complex compound.

On consideration of reaction (2) the question arises as to whether it is reversible and whether alkylphenylchlorohydroxyboric acids (II) can be obtained by addition of hydrogen chloride and water to alkylphenylborinic acids. If such combination is possible, then, taking into account the ability of complex boric acids (II) to decompose in two directions, partial conversion of alkylphenylborinic acids to alkylboronic acids on treatment with hydrogen chloride and water is to be expected. In order to confirm this hypothesis, ethylphenylborinic acid (its preparation will be described below) was treated with an ethereal solution of hydrogen chloride and hydrochloric acid. Benzene was proved to be present in the volatile products of this reaction, and ethylboronic acid was isolated from the residue.

It should be noted that ethylphenylborinic acid remains unchanged on treatment with dry hydrogen chloride in ether.

The results of hydrolysis of alkylphenylboron chlorides by water show that in order to avoid splitting-off of benzene, the hydrogen chloride evolved in the reaction must be bound. Actually, we succeeded in preparing alkylphenylborinic acids by hydrolyzing the chlorides with equimolar quantities of alkali.

On distillation of methyl-, ethyl-, and propylphenylborinic acids, the corresponding anhydrides (V) were obtained. Butylphenylborinic acid disproportionates on distillation. Since the alkylphenylborinic acids could not be purified by distillation, the analytical results for them are naturally somewhat different from the calculated values. On treatment of ethyl- and propylphenylborinic anhydrides with aqueous sodium hydroxide solution the well-crystallized sodium ethyl- and propylphenyldihydroxyborates (VI) are formed.



Salts (VI) are quite stable in aqueous solutions; on treatment of the latter with ether, no alkylphenylborinic acid is extracted.

EXPERIMENTAL

All operations were performed in a dry nitrogen atmosphere.

Alkylphenylborinic acids. To 16.5 ml of 20% sodium hydroxide solution, a solution of 0.1 mole of the alkylphenylboron chloride in an equal volume of ether was added with shaking and cooling in ice water. The emulsion was transferred to a separatory funnel and vigorously shaken. After separation the water layer was treated with 10 ml of ether, and the combined ether extracts were washed twice with water (3 ml portions) and dried with sodium sulfate. The ether was distilled from the filtered solution in vacuo and the residual liquid held for 30 minutes in vacuo (8-10 mm) at room temperature. The acids obtained (Table 1) were colorless liquids with very unpleasant odors; they oxidized extremely rapidly in air; they were miscible with organic solvents and slightly soluble in water.

Alkylphenylborinic anhydrides. When methyl-, ethyl-, and propylphenylborinic acids were heated in vacuo, their anhydrides distilled over (Table 2). On distillation of butylphenylborinic acid, no pure substance could be isolated; the vapor temperature rose continuously from 110 to 165° at 0.3–0.4 mm, and the contents of the receiver consisted of a mixture of liquid and crystals. The residue in the distilling flask was phenylboronic anhydride, m. p. 203–207°.

TABLE 1

Alkylphenylborinic Acids $R(C_6H_5)BOH$

R	Yield (in %)	n_D^{20}	d_4^{20}	Found (%)			Calculated (%)		
				C	H	B	C	H	B
CH ₃	85	1.5202	0.9729	70.55	7.81	8.63	70.09	7.57	9.02
C ₂ H ₅	78.5	1.5102*	0.9514*	71.81	8.30	7.97	71.71	8.27	8.08
n-C ₃ H ₇	82.4	1.5030	0.9429	72.12	9.13	6.87	73.03	8.85	7.31
n-C ₄ H ₉	90	1.4937	0.950	75.55	9.38	6.34	74.12	9.33	6.68

* Measured at 24°.

Hydrolysis of ethylphenylborinic anhydride. A solution of 1 g of ethylphenylborinic anhydride (n_D^{20} , 1.5419) in 3 ml of ether was shaken with 1 ml of water for 1 hour at room temperature. The ether layer was separated and dried with sodium sulfate, and the ether was distilled from the filtered solution; the n_D^{20} of the residue was equal to 1.5130, which nearly corresponds to the refractive index of ethylphenylborinic acid (1.5102).

TABLE 2

Alkylphenylborinic Anhydrides $[R(C_6H_5)B]_2O$

R	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	Found(%)			Calculated (%)		
				C	H	B	C	H	B
CH ₃	137–138°(8)	1.5440	0.9666	75.66	7.37	9.81	75.77	7.27	9.75
C ₂ H ₅	130–132 (3)	1.5419*	0.9526*	77.12	8.26	8.46	76.89	8.07	8.66
n-C ₃ H ₇	156–158 (5)	1.5343	0.9575	77.53	8.83	7.78	77.73	8.70	7.78

* Measured at 24°.

Sodium ethylphenyldihydroxyborate. To 6.6 ml of 20% sodium hydroxide solution was added 5 g of ethylphenylborinic anhydride, which dissolved with appreciable warming. When 7 ml of ether was added to the solution, a homogeneous liquid resulted, which stratified on further addition of ether (8 ml). After removal of the ether from the upper layer, 0.05 g of liquid remained. The lower layer was evaporated to dryness at 90° (18 mm). Sodium ethylphenyldihydroxyborate was obtained in the form of a white powder, with a yield of 6.7 g (96.2%). The latter crystallized from anhydrous acetone in the form of needles.

Found %: B 5.82. $C_8H_{12}O_2BNa$. Calculated %: B 6.22.

Very hygroscopic, deliquesces in air; very soluble in water, soluble in acetone and ether. Aqueous solutions have an alkaline reaction to phenolphthalein.

Sodium propylphenyldihydroxyborate. From 5.5 g of propylphenylborinic anhydride under the conditions described above, 6.7 g (89%) sodium propylphenyldihydroxyborate was obtained.

Found %: C 57.16; H 8.13. $C_9H_{14}O_2BNa$. Calculated %: C 57.49; H 7.55.

The properties of sodium propylphenyldihydroxyborate are similar to those of sodium ethylphenyldihydroxyborate.

Hydrolysis of methylphenylboron chloride by water. To a solution of 3.5 g of methylphenylboron chloride in 5 ml of ether, 1 ml of oxygen-free water was added dropwise with cooling in ice water and shaking. To the homogeneous solution obtained, anhydrous sodium sulfate was added, and the mixture was left for a day. Next day the ether was distilled off the filtered solution under slightly reduced pressure. The weight of the residue was 2.75 g. On further standing at 22° (28 mm) the weight of the liquid continuously changed, being equal to 1.3 g after 6 hours; the loss in weight was 1.45 g (53%). From the residue, which consisted of a thick paste and was probably a mixture of methylboronic and methylphenylborinic acids, no pure substances could be isolated.

On fractionation of the distillate collected in traps at -70°, a mixture of benzene, water, and methylboronic acid was obtained. From the residue a crystalline substance with m. p. 83-87° precipitated out, which consisted of methylboronic acid contaminated by methylphenylborinic acid.

Found %: B 15.6. CH_3O_2B . Calculated %: B 18.07. C_7H_5OB . Calculated %: B 9.02.

Hydrolysis of ethylphenylboron chloride by water. On hydrolysis of 3.8 g of ethylphenylboron chloride under the same conditions, the residue, obtained after distilling off the ether, weighed 3.13 g and consisted of a mixture of liquid and crystals. On standing for 6 hours at 25° (20 mm) the mass crystallized completely, and its weight decreased 1.73 g (55%). The residue was ethylboronic acid, m. p. 73-75°.

Found %: B 14.42. $C_2H_5O_2B$. Calculated %: B 14.64.

Hydrolysis of propylphenylboron chloride by water. A 4.16 g quantity of propylphenylboron chloride was hydrolyzed under the same conditions. After distilling off the ether, 3.34 g of liquid was obtained. On evacuation of the latter for 6 hours at 22° (7 mm) its weight decreased 0.13 g (4%). The product obtained was a mixture of propylphenylborinic and propylboronic acids.

Found %: C 68.83; H 8.77; B 9.39. $C_9H_{13}OB$. Calculated %: C 73.03; H 8.85; B 7.31. $C_3H_7O_2B$. Calculated %: C 40.98; H 10.32; B 12.31.

Hydrolysis of butylphenylboron chloride by water. a) On hydrolysis of 4.5 g of butylphenylboron chloride under the conditions described above, there was obtained butylphenylborinic acid (2.48 g) the weight of which decreased 0.06 g (2.5%) on standing for 6 hours at 21° (8 mm).

Found %: C 73.07; H 8.89; B 6.80. $C_{10}H_{15}OB$. Calculated %: C 74.12; H 9.33; B 6.68.

b) A mixture of 4.5 g of butylphenylboron chloride, 5 ml of ether, and 1 ml of water was shaken and left for 6 days at room temperature. After drying with sodium sulfate the ether was distilled from the liquid in vacuo. On further evacuation at 19° (17 mm) for 1 hour a crystalline precipitate separated from the liquid; it was filtered out and washed with isopentane. The precipitate (0.7 g) was butylboronic acid, m. p. 86-88° (according to cited data [5]; m. p. 92-94°).

Found %: B 10.30. $C_4H_{11}O_2B$. Calculated %: B 10.61.

Effect of hydrogen chloride and water on ethylphenylborinic acid. a) Eight g of ethylphenylborinic acid was mixed with 1.75 ml of 36.5% hydrochloric acid. Slight warming occurred. To the emulsion formed, 15.5 ml of ether containing 0.094 g/ml of HCl was added; in this case pronounced warming and the formation of a homogeneous liquid were observed. The total quantity of hydrogen chloride brought into the reaction was 2.2 g. Anhydrous sodium sulfate was added to the resulting solution; next day the solution was filtered, after which volatile substances were distilled from it in vacuo at room temperature; the residue was kept for 4 hours at 21° (9 mm); in this case colorless crystals separated from the liquid. After the precipitate was filtered out and washed with isopentane, 1.1 g of ethylboronic acid, m. p. 69-72°, was obtained. About 1 ml of benzene, n_D^{20} 1.4995, was isolated by fractionation of the distillate collected in the traps at -70°.

b) To ethylphenylborinic acid was added an equimolar quantity of hydrogen chloride in ether, and the solution was left for 3 days at room temperature. After the ether and hydrogen chloride were distilled off, the ethylphenylborinic acid was isolated unchanged.

SUMMARY

1. Hydrolysis of alkylphenylboron chlorides with equimolar quantities of alkali leads to the formation of the corresponding alkylphenylborinic acids. Methyl-, ethyl-, and propylphenylborinic acids split off water on distillation, being converted to the anhydrides. Butylphenylborinic acid disproportionates on distillation.
2. On treatment of alkylphenylborinic acids with aqueous sodium hydroxide solution, sodium alkylphenyldihydroxyborates are formed.
3. On hydrolysis of alkylphenylboron chlorides by water, mixtures of alkylphenylborinic and alkylboronic acids are formed.

LITERATURE CITED

- [1] K. Torssell, *Acta Chem. Scand.*, 9, 245 (1955).
- [2] B. M. Mikhailov and P. M. Aronovich, *J. Gen. Chem.* 29, 1254 (1959).*
- [3] B. M. Mikhailov and P. M. Aronovich, *Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1956, 322.*
- [4] B. M. Mikhailov and V. A. Vaver, *Proc. Acad. Sci. USSR*, 109, 94 (1956).*
- [5] H. R. Snyder, J. A. Kuck, and J. R. Johnson, *J. Am. Chem. Soc.* 60, 108 (1938).

Received February 24, 1958

*Original Russian pagination. See C.B. Translation.

ON THE MECHANISM OF DECOMPOSITION OF 2-PHENYLISOPROPYL
HYDROPEROXIDE UNDER THE INFLUENCE OF IONS OF METALS OF
VARIABLE VALENCE

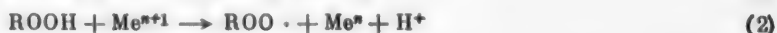
E. I. Tinyakova and T. G. Zhuravleva

Institute of High-Molecular Compounds of the USSR, Academy of Sciences

The study of the effect of ions of metals having variable valence on the decomposition of hydroperoxides is of very substantial importance in connection with the role of these reactions in oxidation, polymerization, and other radical processes.

It is generally known that ions of metals of variable valence in the lower or higher oxidation state catalytically accelerate the decomposition of hydrogen peroxide. The decomposition of hydroperoxides in aqueous solutions at temperatures below 50° and in hydrocarbon solutions at temperatures below 80-100° takes place only under the influence of ferrous ions, the hydroperoxide and the Fe^{2+} ions being consumed in equivalent quantities. In hydrocarbon solutions the catalytic decomposition of the hydroperoxide under the influence of small amounts of ferric ions occurs only at temperatures about 100° or higher, while with a ferrous salt the reaction takes place practically instantaneously even at -70° [1].

The decomposition of hydroperoxides is accelerated also by salts of other metals, e. g., under the influence of Co, Cu, Pd, Mn, Pb, Ag, Cr, Ni, and Fe naphthenates; in this case the activity of the metals decreases in the given order from Co to Fe. With regard to the mechanism of the catalytic effect of the stated metals the hypothesis was advanced [1], that in the system under consideration successive reactions occur in which the hydroperoxide alternately plays the role of oxidizing and reducing agent.



However, this was not proved experimentally. A similar hypothesis was advanced later by Kharasch in order to explain the effect of cobalt ions on the decomposition of tert-butyl hydroperoxide [2].

In the present paper are given experimental data on the decomposition of 2-phenylisopropyl hydroperoxide in the presence of the naphthenates of a series of metals, having variable valence (Mn, Cu, Co, Pd) in various solvents. The results obtained confirm the correctness of the proposed scheme.

The reaction was carried out at 20-60° in benzene, cumene, and olefin solutions. The concentration of hydroperoxide in the solution was 0.33-0.66 M. The quantity of the metal naphthenate varied within a wide range, from 0.5 to 230 mol. % relative to the hydroperoxide. It may be supposed that the character and amount of the products formed must depend on the amount of metal naphthenate introduced and the valence of the metal, as well as the nature of the solvent. On decomposition of 2-phenylisopropyl hydroperoxide in the presence of an equivalent quantity or an excess of the metal ion in its lower valence, reaction (1) alone must take place, since its rate is considerably higher than that of decomposition of the hydroperoxide under the influence of the metal ion in its higher valence. The primary intermediate reaction product in this case consists of $\text{RO} \cdot$ radicals, which, as is generally known, are characterized by high activity in reactions of removal of a H atom from the solvent [3, 7]. Corresponding to this, the main final product of the decomposition of 2-phenyliso-

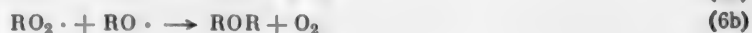
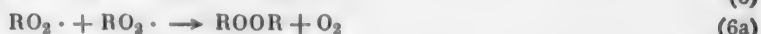
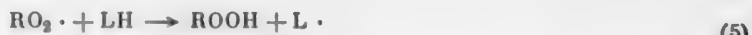
propyl hydroperoxide in the presence of an excess of the naphthenate of a metal in its lower valence must be 2-phenylpropanol-2



A concurrent reaction, the role of which grows as the temperature increases, is the decomposition of the $\text{RO} \cdot$ radical with formation of acetophenone and methyl [4-6].



The total yield of 2-phenylpropanol-2 and acetophenone must be equal to 1 mole per mole of hydroperoxide. On decomposition of the hydroperoxide in the presence of small amounts of salts of metals having variable valence, the process must develop reversibly in accordance with the proposed scheme (Equations 1 and 2) and must be accompanied by the formation of $\text{RO} \cdot$ and $\text{RO}_2 \cdot$ radicals. Products formed with the participation of $\text{RO} \cdot$ radicals are considered above. Reactions which develop with the participation of $\text{RO}_2 \cdot$ radicals may be represented by the following equations.



In solvents active in chain reactions, reaction (5) will predominate and the original hydroperoxide will be regenerated. This reaction should become much less important on transition to such a solvent as benzene, and therefore the role of radical-recombination reactions accompanied by the evolution of oxygen (Equations 6a and 6b) will be enhanced. When α -olefins and, especially, conjugated dienes are used as solvents, acts of addition of the free radicals $\text{RO}_2 \cdot$ and $\text{RO} \cdot$ may prevail owing to the high reactivity of the double bonds, consequently reaction (6), in which oxygen is evolved, must be excluded.

Evolution of Oxygen on Decomposition of the Hydroperoxide

In Table 1 are given data characterizing the yield of oxygen on decomposition of 2-phenylisopropyl hydroperoxide under various conditions. The decomposition of 2-phenylisopropylhydroperoxide in benzene solution in the presence of small amounts of the naphthenate of cobalt, manganese, copper, or palladium (0.5-5.0 mol. % relative to the hydroperoxide) goes to completion and is accompanied by the evolution of considerable amounts of oxygen (up to 0.34 mole per mole of hydroperoxide). As the amount of the naphthenate of the metal in its lower valence is increased, as is evident from the data of Table 1, the yield of oxygen falls, and when the reaction is carried out with an excess of the naphthenate of Co^{++} , Mn^{++} , or Cu^{++} , so that reaction (1) takes place practically exclusively, the decomposition of the hydroperoxide is not accompanied by oxygen evolution. On decomposition of 2-phenylisopropyl hydroperoxide under the influence of small amounts of cobalt naphthenate (1-5 mol. %) dissolved in isopropylbenzene, which is more active in acts of chain transmission, quite vigorous evolution of oxygen in amounts approaching 0.15 mole per mole of hydroperoxide is observed in the first moment after the components are mixed. In isopropylbenzene solution at a high concentration of $\text{RO}_2 \cdot$ radicals and a temperature up to 60° , therefore, reaction (5) takes place along with reaction (6). It must be noted that unless the buret is disconnected from the reaction vessel at the end of the vigorous reaction accompanied by oxygen evolution, the reverse process of quite rapid oxygen absorption begins, which is accelerated on shaking the reaction mixture. When the experiments are performed in sealed ampules, oxygen is generally not found.

The decomposition of 2-phenylisopropyl hydroperoxide in the presence of metal naphthenates, dissolved α - and β -olefins and conjugated dienes, takes place without oxygen evolution. Comparison of data on the yield of oxygen in cumene and olefin solutions also indicates that cumene has relatively low activity in acts of chain transmission at low temperatures.

As was noted above, oxygen evolution may be due to recombination reactions of two $\text{RO}_2 \cdot$ radicals or of an $\text{RO}_2 \cdot$ and an $\text{RO} \cdot$ radical (reactions 6a and 6b). The simultaneous occurrence of these two reactions is

Indicated by a high yield of oxygen (up to 0.34 mole per mole of hydroperoxide), whereas the maximum yield of oxygen in reaction (6a) cannot exceed 0.25 mole per mole of hydroperoxide. Reaction (6b) apparently is of a subordinate nature.

TABLE 1

Yield of Oxygen in the Decomposition of 2-Phenylisopropyl Hydroperoxide (ROOH) in Various Solvents in the Presence of the Naphthenate of Co^{2+} , Cu^{2+} , Mn^{2+} , or Pd^{2+} (Temperature 60° ; hydroperoxide concentration 0.3-0.6 M)

Solvent	Metal naphthenate and its conc. (in mol. % relative to ROOH)	Yield of oxygen (in moles/ mole of ROOH)	Solvent	Metal naphthenate and its conc. (in mol. % relative to ROOH)	Yield of oxygen (in moles/ mole of ROOH)
C_6H_6	Co^{2+} 0.5	0.30-0.34**	$\text{C}_6\text{H}_5\text{CH}(\text{CH}_3)_2$	Co^{2+} 1.0	0.15
	Co^{2+} 1.0	0.32-0.34**		Co^{2+} 5.0	0.07
	Co^{2+} 5.0	0.30-0.33**		Co^{2+} 5.0	0*
	Mn^{2+} 5.0	0.25-0.28		Co^{2+} 5.0	0
	Cu^{2+} 5.0	0.23-0.25		Mn^{2+} 5.0	0
	Pd^{2+} 5.0	0.26-0.28		Co^{2+} 0.5-1.0	0
	Co^{2+} 100	0.15		Co^{2+} 0.5-1.0	0
	Cu^{2+} 100	0.15		Co^{2+} 0.5-1.0	0
	Co^{2+} 230	0		Co^{2+} 5.0	0
	Mn^{2+} 230	0			
	Cu^{2+} 230	0			
			$\text{CH}_3\text{CH}=\text{CHC}_2\text{H}_5$		
			$\text{CH}_2=\text{C}(\text{CH}_3)\text{C}_2\text{H}_5$		
			$\text{CH}_2=\text{C}(\text{CH}_3)_2$		
			$\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}=\text{CH}_2$		
			$\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$		
			$\text{CH}_2=\text{C}(\text{CH}_3)\text{C}_6\text{H}_5$		

* Experiments in sealed ampoules.

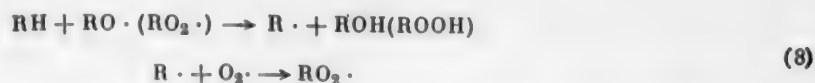
** The gas contains a certain amount of CO and CO_2 , apparently formed as a result of the reaction of $\text{CH}_3\cdot$ with oxygen [17].

Composition of Liquid Reaction Products

The principal products of the decomposition of 2-phenylisopropylhydroperoxide, isolated from the reaction mixture, were 2-phenylpropanol-2 and acetophenone. The corresponding experimental data are given in Table 2.

On decomposition of 2-phenylisopropyl hydroperoxide in benzene solution under the influence of an equivalent or excess quantity of a salt of a metal in its lower valence, the total yield of 2-phenylpropanol-2 (0.78 mole) and acetophenone (0.15 mole) was close to the theoretical. On decomposition in the presence of small amounts of ions of the stated metals, the yield of 2-phenylpropanol-2, as was to be expected, was substantially lower than on decomposition with an excess of Me^{II} . The yield of acetophenone depends only slightly on the concentration of the metal salt. The products of decomposition of 2-phenylisopropyl hydroperoxide under these conditions include cumyl peroxide. The amount of cumyl peroxide determined amounted to about 0.06 mole in different experiments. On decomposition of the hydroperoxide in the presence of small amounts of metal naphthenates, dissolved in α - and β -pentenes containing active α -methylene groups, the main reaction product is 2-phenylpropanol-2 (its yield in the case of decomposition in β -pentene was 0.97 mole per mole of hydroperoxide). In solution in isobutylene and especially in conjugated dienes (isoprene, divinyl) the yield of 2-phenylpropanol-2 was about 0.5 mole per mole of hydroperoxide, which indicates that $\text{RO}_2\cdot$ radicals add to the double bonds of these compounds to form the corresponding peroxides. Similar peroxides were isolated by Kharasch [8] at 0° . Hargrave [9] states that such reactions are possible at higher temperatures. The yield of acetophenone in the decomposition products of the hydroperoxide in olefins is sharply reduced, which indicates that the lifetime of $\text{RO}\cdot$ radicals is shorter in olefins than in benzene or cumene, and that olefins have high activity in acts of chain transmission. The high yield of 2-phenylpropanol-2 in olefins is caused by the energetic efficiency of reaction (3) and characterizes the high activity of $\text{RO}\cdot$ radicals in acts of removal of H atoms, which greatly exceeds the activity of the methyl radical - the most active of aliphatic radicals [16] - in this

reaction. On carrying out the reaction under the same conditions in cumene solution, there is a sharp increase in the yield of 2-phenylpropanol-2, the amount of which rises to 1.4 moles per mole of hydroperoxide. The reaction products also contain acetophenone, the yield of which is nearly the same as on decomposition in benzene. The total yield of these products, which reaches 1.54 moles, considerably exceeds the theoretical. The presence of dicumyl in the reaction products has been established. The excessive yield of 2-phenylpropanol-2 and acetophenone based on the theoretical values may be explained on the basis of the established fact that $RO_2\cdot$ radicals in cumene solution take part not only in reaction (5), but also in reaction (6), which leads to oxygen evolution. The oxygen is quantitatively absorbed by the cumyl radical $R\cdot$, which is formed in the reaction of $RO\cdot$ or $RO_2\cdot$ radicals with the solvent.



The entire complex of reactions leads in the end to the formation of a new, additional quantity of 2-phenylisopropyl hydroperoxide, which in turn leads to an increase in the yield of 2-phenylpropanol-2. The low apparent rate of decomposition of 2-phenylisopropyl hydroperoxide dissolved in cumene, toluene, and other solvents in comparison with its rate of decomposition in benzene (Fig. 1), where the kinetic curve approximates

TABLE 2

Composition of the Products of Decomposition of 2-Phenylisopropyl Hydroperoxide in the Presence of Metal Naphthenates in Various Solvents

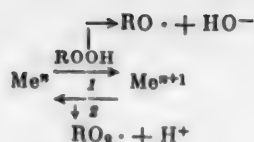
Solvent	Conc. of cobalt naphthenate (in mol. %)	Yield (in moles/ mole of ROOH)			
		ROH	> C=O	ROOR	R-R
Benzene	200	0.78	0.15	—	—
	1	0.52	0.20	—	—
	5	0.47—0.54	0.15—0.19	0.06	—
	5*	0.43	0.15	0.06	—
β -Pentene	5	0.97	0.04	—	—
α -Pentene	5	0.92	0.08	—	—
Isobutylene	0.5—1.0	0.54	0.013	—	—
Isoprene	0.5—1.0	0.49	0.02	—	—
Cumene	5	1.29	0.15	—	—
	5	1.18	0.15	—	—
	1	1.39**	0.14	—	0.38

*Manganese naphthenate in the given case.

**In a sealed ampule.

the actual kinetics of decomposition, may be explained by the evolution of oxygen on decomposition of the hydroperoxide. The visible decrease in the decomposition rate in alkylbenzenes is due to regeneration of the hydroperoxide as a result of reaction of the $RO_2\cdot$ radical with the solvents. The meaning of the inhibiting effect of oxygen on the kinetics of decomposition of hydroperoxides apparently consists in this [10, 11].

It follows from the given experimental data that in a system containing 2-phenylisopropyl hydroperoxide and ions of metals having variable valence, a cycle of reversible oxidation-reduction conversions is established, in which the hydroperoxide acts alternately as an oxidizing and a reducing agent. The over-all rate of the process is determined by the rate of reaction (2). In those cases where the oxidation potential of the metal ion in its higher valence is high, this reaction may take place even at relatively low temperatures (30–60°), which makes it possible to carry out the process in the presence of insignificant amounts of salts of metal having variable valence (e. g., naphthenates of cobalt, manganese, etc.) (Fig. 2). The higher-valence ions of metals having



lower oxidation potentials (e. g., $\text{Fe}^{+++} + e \rightarrow \text{Fe}^{++} + 0.77 \text{ v}$; $\text{Cr}^{+++} + e \rightarrow \text{Cr}^{++} - 0.41 \text{ v}$) reduce the hydroperoxide at a higher temperature ($70-100^\circ$), which makes it necessary to use higher concentrations of the salts of these metals in order to obtain the required effect. On the basis of the complete similarity between the behavior of Cu^{++} naphthenate and that of Co^{++} , Mn^{++} , and Pd^{++} naphthenates, it may be supposed that the higher-valence copper ion in the given reaction is Cu^{+++} and not Cu^{++} (in this case the latter is the lower-valence

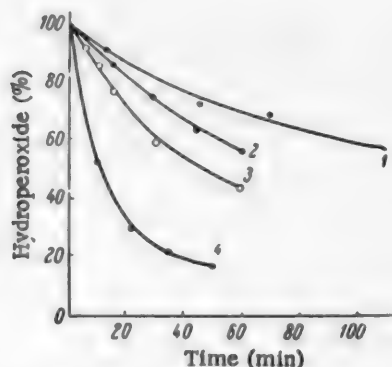


Fig. 1. Kinetics of decomposition of 2-phenylisopropyl hydroperoxide under the influence of Mn naphthenate (0.5 mol. % relative to the hydroperoxide) at 60° in various solvents. 1) Cumene; 2) α -methylstyrene; 3) toluene; 4) benzene.

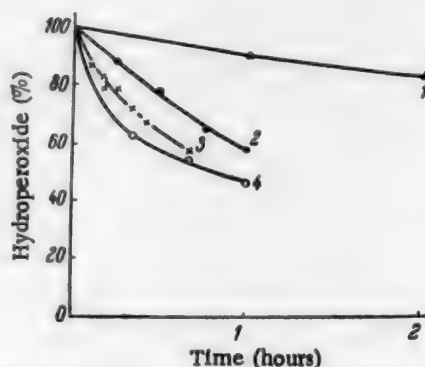


Fig. 2. Kinetics of decomposition of 2-phenylisopropyl hydroperoxide dissolved in toluene (1, 2, 3) and benzene (4), in the presence of Fe^{+++} , Mn^{++} , and Co^{++} naphthenates. 1) 100° , Fe^{+++} naphthenate (10 mol. % relative to the hydroperoxide); 2) 60° , Mn^{++} naphthenate (0.5 mol. % relative to the hydroperoxide); 3) 60° , Co^{++} naphthenate (0.5 mol. % relative to the hydroperoxide); 4) 35° , Co^{++} naphthenate (0.5 mol. % relative to the hydroperoxide).

ion); this is indirectly supported by the proximity of the standard oxidation potentials of the stated ions [12]: $\text{Co}^{+++} + e \rightarrow \text{Co}^{++} + 1.84 \text{ v}$, $\text{Mn}^{++++} + 2e \rightarrow \text{Mn}^{++} + 1.84 \text{ v}$, $\text{Cu}^{+++} + e \rightarrow \text{Cu}^{++} + 1.80 \text{ v}$, $\text{Pd}^{++++} + 2e \rightarrow \text{Pd}^{++} + 1.60 \text{ v}$, and $\text{Pb}^{++++} + 2e \rightarrow \text{Pb}^{++} + 1.64 \text{ v}$, while the oxidation potential for $\text{Cu}^{++} + e \rightarrow \text{Cu}^+$ is equal to $+0.167 \text{ v}$.

The results obtained make it possible to approach the consideration of the mechanism of the decomposition of hydrogen peroxide under the influence of salts of metals having variable valence from the same viewpoint. In connection with the more pronounced reducing properties of hydrogen peroxide, its decomposition under the influence of higher-valence ions of heavy metals occurs at a lower temperature than the decomposition of the hydroperoxide. However, the views expressed with respect to the mechanism of decomposition of hydrogen peroxide require experimental confirmation.

EXPERIMENTAL

The 2-phenylisopropyl hydroperoxide was purified through the sodium salt [15]. The petroleum ether, in which the salt was decomposed, was distilled from the hydroperoxide in vacuo at a temperature not over $40-45^\circ$. The product contained 99.2-99.7% hydroperoxide. The benzene, toluene, and cumene were treated with sulfuric acid, washed with water, dried over calcium chloride, and distilled. The metal naphthenates were prepared by metathesis from potassium naphthenate. The molecular weight of the naphthenic acids used was 203-215.

Experimental procedure. The decomposition of 2-phenylisopropyl hydroperoxide, dissolved in benzene or cumene, in the presence of small amounts of metal salts was carried out in special ampules (Figure 3), filled in an oxygen-free nitrogen atmosphere. A weighed portion of the metal naphthenate was put into one bulb of the ampule, and the latter was evacuated three times by an oil pump, the vacuum being destroyed each time with nitrogen. The required quantity of benzene was then added to the portion of naphthenate in a countercurrent of nitrogen, and the benzene and hydroperoxide* were put into the other bulb, after which one arm was sealed. The side arm of the ampule, provided with a condenser, was connected to a gas buret and the ampule placed in a thermostat. After constant volume was established, the two solutions were mixed and the quantity of gas evolved was measured. At the end of the reaction all the gas was expelled from the system, by means of benzene, into the buret and analyzed for O_2 , CO_2 , CO , and CH_4 .

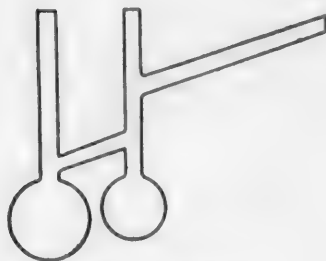


Fig. 3. Reaction ampule.

The decomposition of the hydroperoxide in the presence of an excess of the naphthenate of a metal in its lower valence was carried out in a flask provided with a graduated dropping funnel. In this case a solution of the hydroperoxide in benzene was slowly added from the dropping funnel to a solution of the lower-valence metal naphthenate in benzene. After all the hydroperoxide was added, the reaction mixture was kept at 60° for 2-3 hours. Determination of the completeness of decomposition of the hydroperoxide under these conditions was preceded by removal of the higher-valence metal ions from the solution by treatment with anthranilic acid. It was shown by special experiments that the higher-valence metal ions are practically completely removed by this treatment, while the hydroperoxide remains unchanged. Decomposition of the hydroperoxide, dissolved in olefins, under the influence of metal naphthenates was carried out, as a rule, in sealed ampules which had been filled in a nitrogen atmosphere. To prevent the reaction from taking place during the process of filling, each ampule was cooled to -78° before the components were put in.

At the end of the reaction the completeness of decomposition of the hydroperoxide and the yields of the resulting 2-phenylpropanol-2, acetophenone, dicumyl peroxide (on decomposition in benzene), and dicumyl (on decomposition in cumene) were determined. The 2-phenylpropanol-2 and acetophenone were distilled from the reaction mixture in vacuo, along with the solvent.

In order to determine the yield of dicumyl, the reaction mixture was treated with hydrochloric acid (1 : 1) for removal of metal ions, after which the solvent and the bulk of the 2-phenylpropanol-2 and acetophenone were distilled off in vacuo. When the residue was cooled and methyl alcohol added, crystals of dicumyl separated out; the latter was characterized by its melting point.

Analytical procedure. The hydroperoxide was determined iodometrically [1]. The determination of dicumyl peroxide in the crude reaction mixture by reaction with concentrated HI [13] was impossible, since the 2-phenylpropanol-2 present in the mixture also liberates iodine from HI. For this reason dicumyl peroxide was determined indirectly from the quantity of methane evolved on decomposition of the reaction mixture in cumene solution. According to the data of Kharasch [5], the decomposition of dicumyl peroxide at 135° is finished within 3 hours. From 1 mole of peroxide, 1.15 moles of methane is evolved.

In order to determine the yield of dicumyl peroxide, the benzene was distilled from the reaction mixture in vacuo at room temperature. The residue was dissolved in cumene, and the ampule was heated at 135° in a thermostat. When the evolution of gas was ended, the content of methane in the latter was determined.

2-Phenylpropanol-2 was determined through the hydrochlorination reaction [14]; acetophenone was determined through its reaction with hydroxylamine hydrochloride [14].

SUMMARY

1. It has been shown that on reaction with higher-valence ions of metals having variable valence, a hydroperoxide acts as a reducing agent. The reaction is accompanied by the formation of $RO_2 \cdot$ radicals. In

*In determining the yield of oxygen the weighed portion of hydroperoxide amounted to 0.5-1.0 g. In determining total reaction products the hydroperoxide was taken in 5-40 g quantities.

the absence of active donors of hydrogen or acceptors of free radicals the reaction is accompanied by the evolution of oxygen as a result of acts of recombination taking place with the participation of RO_2^{\cdot} radicals.

2. It has been established that the decomposition of a hydroperoxide in the presence of insignificant quantities of ions of metals having variable valence takes place as a reversible process in which the hydroperoxide acts alternately as oxidizing and reducing agent.

LITERATURE CITED

- [1] B. A. Dolgoplosk, E. L. Tinyakova, and M. B. Rabinovich, Wks. of VNIISK for 1947-1950. "Investigation in the field of polymerization under the influence of free radicals," p. 149; Bull. Acad. Sci. USSR, Div. Chem. Sci. 1957, 702.*
- [2] M. S. Kharasch, A. Fono, W. Nudenberg, and C. Bischof, J. Org. Ch. 17, 207 (1952).
- [3] E. H. Farmer and C. G. Moore, J. Chem. Soc., 131, 142 (1951).
- [4] J. H. Raley, F. F. Rust, and W. E. Vaughan, J. Am. Chem. Soc. 70, 1336 (1948).
- [5] M. S. Kharasch, A. Fono, and W. Nudenberg, J. Org. Ch. 16, 105 (1951).
- [6] H. C. Bailey and G. W. Godin, Trans. Far. Soc., 52, 68 (1956).
- [7] J. H. Brook, Trans. Far. Soc. 53, 327 (1957).
- [8] M. S. Kharasch, P. Pauson, and W. Nudenberg, J. Org. Ch. 18, 322 (1953).
- [9] K. R. Hargrave and A. L. Morris, Trans. Far. Soc. 52, 89 (1956).
- [10] V. Stannet and R. Mesrobian, J. Am. Chem. Soc. 72, 4125 (1950).
- [11] B. K. Morse, J. Am. Chem. Soc., 79, 3375 (1957).
- [12] Handbook. Chem., V. 3. State Chem. Press, 552 (1952).**
- [13] F. H. Dickey, J. H. Raley, F. F. Rust, R. S. Treseder, and W. Vaughan, Ind. Eng. Ch. 41, 1673 (1949).
- [14] Collection of Instructions of Analytical Methods Used in the Control of α -Methylstyrene Production, VNIISK (1954).**
- [15] H. Hock and G. Lang, Ber. 77, 257 (1944).
- [16] E. B. Milovskaya, B. A. Dolgoplosk, and B. L. Erusalimskii, Bull. Acad. Sci. USSR, Div. Chem. Sci. 1957, 494.*
- [17] J. H. Raley, L. M. Porter, F. F. Rust, and W. E. Vaughan, J. Am. Chem. Soc., 73, 15 (1951).

Received March 3, 1958

*Original Russian pagination. See C.B. Translation.

** In Russian.

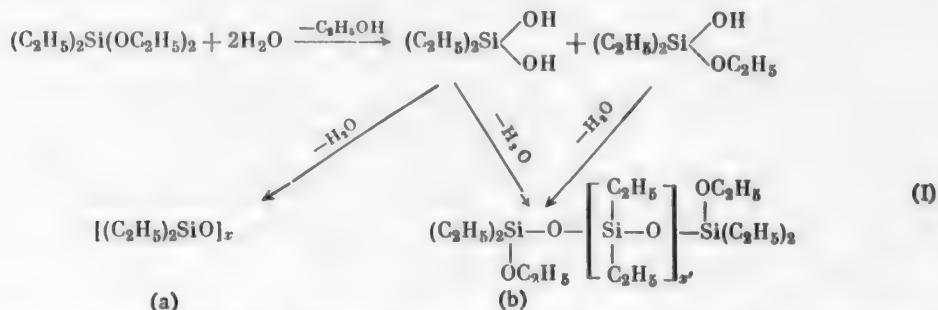
POLYDIETHYLSILOXANE LIQUIDS

I. ACTION OF SULFURIC ACID ON DIETHYLDIETHOXYSILOXANE AND ITS MIXTURES WITH TRIETHYLETHOXYSILOXANE

N. S. Leznov, L. A. Sabun, and K. A. Andrianov

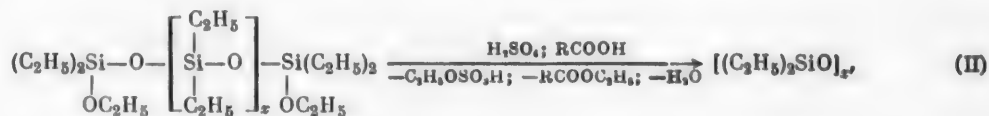
Data, obtained in work carried out by us in 1947, and devoted to the investigation of reactions of formation of liquid polydiethylsiloxanes from diethyldiethoxysilane and its mixtures with triethylethoxysilane, are given in the present paper. The purpose of the investigation was to prepare polymeric liquids, free from admixtures of polymers containing ethoxy groups in the molecule.

The hydrolysis of diethyldiethoxysilane in aqueous media at temperatures up to 100° led to the formation of diethyldihydroxy- and diethylhydroxyethoxysilanes, which were converted further to polydiethylsiloxanes of cyclic and linear structure according to scheme (I).

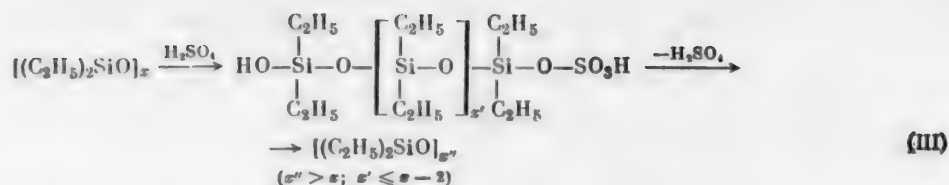


The formation of polymers containing ethoxy groups in the molecule (b) could not be avoided by changing the conditions of the process; it was difficult to follow the hydrolysis of these groups in the polymer, owing to their low concentration, the diminished polarizability of the $-\text{Si}-\text{O}-\text{C}-$ bond, and the hydrophobic character of the polymeric compound.

The preparation of polydiethylsiloxanes, free from ethoxy groups, from the hydrolysis products of diethyl diethoxysilane was carried out by treating them with 93-100% sulfuric acid at 20-50°, and also by treating them with 95-99% formic or acetic acid at 60-100° according to scheme (II).



When sulfuric acid was used, the fractional composition of the polydiethylsiloxanes changed sharply in favor of polymers of high average molecular weight partly as a result of condensation of linear polymers in the place of the removed ethoxy groups, but mainly owing to rearrangement of cyclic polymers according to scheme (III).



Treatment with carboxylic acids did not cause rearrangement of cyclic polymers, and the fractional composition was changed only on account of condensation of molecules of linear structure according to scheme (II) (Table 1).

TABLE 1

Action of Acids on Polydiethylsiloxanes Containing Ethoxy Groups

Starting materials						Polydiethylsiloxanes obtained				
polydiethylsiloxanes			96% sul-	acetic	99.2%	weight (in g)	boiling range of fractions (1 mm)	yield fractions (1mm)	found (%)	
weight (in g)	boiling range (1 mm)	content of OC_2H_5 (in %)	furic acid (g)	acid (g)	formic acid (g)				OC_2H_5	Si
200	120-180°	10.5	20	—	—	182	120-250°	70	4.3	—
200	120-180	10.5	40	—	—	180	120-250	66	0.63	—
200	120-180	10.5	50	—	—	179	140-250	63	0.0	27.28
450	185-250	1.05	—	10	—	413	185-250	94	0.0	27.31
170	185-250	0.25	—	2	—	165	185-250	92	0.0	27.42
200	150-185	3.32	—	—	8	190	150-185	91	0.0	27.49

Note. Calculated content of silicon in one link of the cyclic polymer, 27.45%.

On the basis of the above, one could assume the possibility of preparing polydiethylsiloxanes free from admixtures of polymers containing ethoxy groups in the molecule by treating diethyldiethoxysilane with concentrated acids, particularly sulfuric, according to the general scheme (IV). The given scheme was experimentally confirmed. Treating of diethyldiethoxysilane with 90-100% sulfuric acid led to the formation of



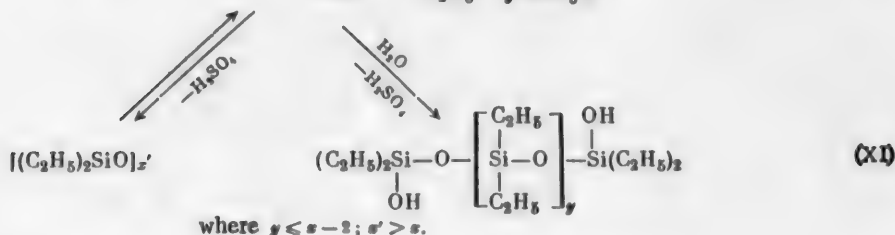
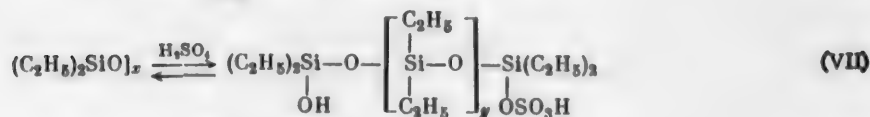
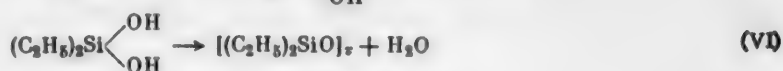
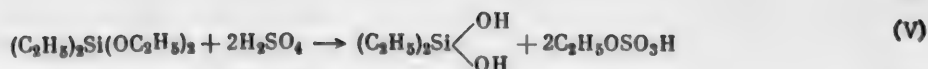
ethylsulfuric acid and cyclic polydiethylsiloxanes, free from admixtures of linear polymers having ethoxy groups in the molecule; the yield reached 98%. Diethyl sulfate was not found in the reaction products. At a temperature higher than 110°, the formation of diethyl ether was observed.

On the basis of investigation of the influence of various factors on the process and on the composition of the polydiethylsiloxanes formed, the principal chemical transformations may be represented by schemes (V)-(IX).

To the extent to which reaction water accumulates in a system containing an insufficient concentration of sulfuric acid, aqueous hydrolysis of diethyldiethoxysilane takes place according to scheme (V).

The given schemes are supported by experimental data. Cyclic polydiethylsiloxanes may be obtained with an amount of sulfuric acid equal to 90% of that calculated according to scheme (IV), which indicates that the diethyldiethoxysilane is concurrently hydrolyzed by the water formed in the reaction and that introduced with the sulfuric acid.

If the amount of sulfuric acid is increased to the molar ratios 2 : 1 and 2.2 : 1, polydiethylsiloxanes of higher molecular weight are formed (Table 2), which indicates that the cyclic polymers initially formed (scheme VI) are rearranged under the influence of free sulfuric acid according to scheme (VIII). Increase in



the acid concentration above 94% has a similar effect on the fractional composition of polydiethylsiloxanes both at 1.8 : 1 and 2 : 1 ratios (Table 3). The joint influence of the increased quantity of sulfuric acid and increased concentration of the latter results in a more pronounced change in the fractional composition and an appreciable decrease in the yield of polydiethylsiloxanes (Table 3). This decrease is due to the greater stability of polydiethylsiloxane sulfates (scheme VII); they remain unchanged and partially dissolve in ethylsulfuric acid, from which they can be isolated on further treatment with water (depending on the conditions), in the form of cyclic polymers according to scheme (VIII) or linear polymers according to scheme (IX).

TABLE 2

Effect of Quantitative Ratios of Sulfuric Acid and Diethyldiethoxysilane on the Chemical and Fractional Composition of Polydiethylsiloxanes (in all experiments 1 mole of diethyldiethoxysilane was taken; temperature 50°)

Initial amount of 95% sulfuric acid (moles)	Reaction time in (in hrs)	Yield of polydiethylsiloxanes (in %)	Characteristics of polydiethylsiloxanes							viscosity of still-pot residue at 20° (in cst.)
			content (in %)		fractional composition at 1 mm (in %)					
			C ₂ H ₆ O	Si	100—110°	110—150°	150—185°	185—250°	still-pot residue	
1	6	94.7	10.62	23.72	—	—	—	—	—	—
1.5	6	94.6	1.62	26.01	—	—	—	—	—	—
1.8	3	94.8	0	27.15	3	22	19	35	21	278
2	3	94.6	0	27.32	4	19	17	25	35	584
2.2	3	92.8	0	27.54	0	8	12	18	52	914

Note. Calculated content of silicon in one link of the cyclic polymer, 27.45%.

The above-mentioned influence of the concentration and quantity of acid is eliminated if the reaction is carried out in an inert solvent (benzene, toluene) (Table 3). In this case, owing to the reduced concentration of the cyclic polymers first formed, as well as the more rapid separation of the phases polydiethylsiloxanes — ethylsulfuric and sulfuric acids, the possibility and duration of contact of the sulfuric acid with the cyclic polymers decreased, and the reaction according to scheme (VIII) may be suppressed.

The temperature factor affects all the reactions in the given schemes. It determines the yield and the chemical and fractional composition of the polydiethylsiloxanes. Under conditions favorable to the formation

of polydiethylsiloxanes of higher molecular weight, an increased reaction temperature hinders their formation owing to a shift of equilibrium to the left in scheme (VIII) (Table 4). The reaction according to scheme (IX) practically does not take place at high temperature, since in this case the rate at which polydiethylsiloxane sulfates react to regenerate sulfuric acid is sharply increased, and the stated compounds do not occur in the reaction

TABLE 3

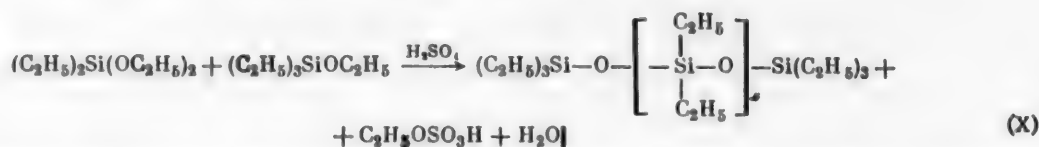
Influence of the Sulfuric Acid Concentration on the Chemical and Fractional Composition of Polydiethylsiloxanes (In all experiments 1 mole of diethyldiethoxysilane was taken; temperature 50°)

No. of expt.	Initial am't of sulfuric acid		Duration (in hours)	Yield of polydiethylsiloxanes (in %)	Characteristics of polydiethylsiloxanes								Viscosity of still-pot residue at 20° (in csp)
	(moles)	concentration (in %)			content (in %)		fractional composition at 1 mm (in %)						
					OC ₂ H ₅	Si	100—110°	110—150°	150—185°	185—250°	still-pot resi- due		
1	2	99.8	1	88.2	0	27.42	0	13	21	22	44	690	
2	2	93	1	92.1	0	27.35	3	38	21.5	22.5	12.00	506	
3	2	90	1	92.2	0	27.38	0	59.2	30.6	6.3	3.9	125.7	
4	2	85	1	95.7	1.34	26.69	—	—	—	—	—	—	
5	1.8	99.8	3	89.3	0	27.41	0	18	21	22.3	39.7	782	
6	1.8	95	3	93.1	0	27.39	3	21	22	28	26	387	
7	1.8	90	3	93.6	0	27.49	4	24	19	28	25	282	
8	1.8	85	3	94.6	0	27.35	3	24	22	29	22	230	
9	1.8	80	5	96.2	1.26	26.37	—	—	—	—	—	—	
10*	2	99.8	1	93	0	27.58	4	45	19.2	19.2	12.6	276	
11*	1.8	95	3	94	0	27.28	4	33	25	26	12	272	

* In Experiments 10 and 11 the diethyldiethoxysilane was taken in the form of a 65% solution in toluene.

mixture (Table 4). An increase of temperature promotes the formation of polydiethylsiloxanes free from admixtures of linear polymers containing ethoxy groups in the molecule, provided acid is present in the proper quantity and concentration (Table 4).

Treatment of a mixture of diethyldiethoxysilane and triethylethoxysilane with sulfuric acid led to the formation of polydiethylsiloxanes in which linear polymers with triethylsilyl groups at the ends of the molecular chain predominate, according to the general scheme (X).



Besides linear polymers, the reaction product contained admixtures of cyclic polymers and hexaethylsiloxane. By increasing the proportion of triethylethoxysilane in the initial mixture, the amount of cyclic polymers may be reduced to a minimum and the average molecular weight of the polydiethylsiloxane mixture formed, lowered.

In contrast to the reaction of sulfuric acid with diethyldiethoxysilane, in reactions with a mixture containing triethylethoxysilane, increases in the concentration and quantity of sulfuric acid have no effect on the average molecular weight of the polydiethylsiloxanes formed. Triethylsilyl derivatives present in the mixture

TABLE 4

Influence of Temperature on the Chemical and Fractional Composition of Polydiethylsiloxanes (In all experiments 1 mole of diethyldiethoxysilane was taken)

No. of expt.	Initial am't of sulfuric acid		Reaction temperature	Duration (in hrs.)	Yield of polydiethylsiloxanes (in %)	Characteristics of polydiethylsiloxanes							
	(moles)	concentration (%)				content (in %)		fractional composition at 1 mm (in %)					viscosity of still-pot residue at 20° (in cent.)
						OC ₂ H ₅	Si	100—110°	110—150°	150—185°	185—250°	still-pot residue	
1	1.8	94	20°	3	90.4	1.76	—	—	—	—	—	—	—
2	1.8	94	40	3	93.4	0.23	26.7	4	27	20	24	25	237
3	1.8	94	75	3	94.6	0	27.22	3	28	22	25	22	229
4	1.8	80	75	6	90.0	1.03	—	—	—	—	—	—	—
5	1.8	80	100	10	89.5	0.93	—	—	—	—	—	—	—
6*	2	99.8	20	1	86.4	0	26.93	—	25	13	16	46	724
7	2	99.8	40	1	92.2	0	27.39	—	13	20	28	39	699
8	2	99.8	75	1	92.2	0	27.44	4	40	17	19	19	396

* When the distillation temperature reached 189°, vigorous evolution of water took place.

wholly or partly prevent the formation of polydiethylsiloxane sulfates and the reaction according to scheme (VIII) by blocking the terminal links of the growing polymer chain with triethylsilyl groups.

The temperature factor has the same effect in reactions of sulfuric acid with mixtures of diethyldiethoxysilane and triethylethoxysilane as in reactions with diethyldiethoxysilane alone. At decreased temperatures the stability of polydiethylsiloxane sulfates is increased, as a result of which the latter partially dissolve in the polydiethylsiloxanes; subsequent washing of this solution with water causes hydrolysis of the sulfates with formation of admixtures of linear polymers with hydroxyl groups in the molecule (scheme IX).

TABLE 5

Action of Sulfuric Acid on a Mixture of Ethylethoxysilanes (In all experiments 1 mole of triethylethoxysilane was taken)

Initial amount (moles)		Yield of polydiethylsiloxanes (in %)	Fractional composition of polydiethylsiloxanes at 1 mm (in %)					Viscosity of residue at 20° (in cat.)	Content of Si in fractions boiling above 100° (in %)*
diethyl-diethoxy-silane	96% sulfuric acid		75—100°	100—150°	150—180°	185—250°	still-pot residue		
0.5	2	93.6	38	43	12	—	7	—	24.06
1	3	92.4	22	38	16	21	3	131	24.98
2	5	92.5	12	31	32	17	8	116	25.12
3	7	95.1	8	30	38	20	4	127	25.78
5	11	94.4	0	23	36	31	10	139	26.18

* No OC₂H₅ groups were present; the calculated content of silicon in octaethyltri-siloxane is 24.16%, and that in octadecaethyloctasiloxane is 26.12%.

EXPERIMENTAL

1. Action of acids of polydiethylsiloxanes containing polymers with ethoxy groups in the molecule.

Polydiethylsiloxanes obtained by the aqueous hydrolysis of diethyldiethoxysilane were treated with stirring for 1 hour at 50° (with 96% sulfuric acid), 2 hours at 70° (with 99.2% formic acid), and 3 hours at 90° (with glacial acetic acid). The reaction mixture was washed with water, the water layer was drawn off, and the remaining polydiethylsiloxane liquid was neutralized with 1% sodium carbonate solution (to phenolphthalein) and then washed with water until a neutral reaction was obtained. The liquid was dried with calcium chloride and distilled in vacuo. In Table 1 are given data from certain experiments, characterizing the variation in the chemical and fractional composition of the polydiethylsiloxanes with the nature of the acid.

2. Action of sulfuric acid on diethyldiethoxysilane. Sulfuric acid was added to diethyldiethoxysilane (or to its toluene solution) during 15-20 minutes with vigorous stirring and external cooling. At the end of the operation the stirring was stopped and the reaction mixture cooled to room temperature. The separated ethyl-sulfuric acid layer was poured off, and the remaining liquid was washed and treated as in 1. When solutions in benzene or toluene were used, the solvents were removed by heating to 130-150° at 50 mm. In Tables 2-4 are given data from certain experiments, characterizing the yield and the chemical and fractional composition of the polydiethylsiloxanes in relation to conditions and initial reactants.

3. Action of sulfuric acid on a mixture of diethyldiethoxysilane and triethylethoxysilane. Experiments with a mixture of ethylethoxysilanes were carried out under the conditions of 2 at 75° with a 3-hour acid-addition period. Data from certain experiments are given in Table 5.

SUMMARY

The reaction of sulfuric acid with diethyldiethoxysilane and mixtures of the latter with triethylethoxysilane has been investigated. The possibility of preparing polydiethylsiloxanes, free from admixtures of polymers containing functional groups, has been established. The influence of various factors of the reaction on the chemical and fractional composition of the polydiethylsiloxanes has been demonstrated.

Received March 10, 1958

POLYDIETHYLSILOXANE LIQUIDS

II. ACTION OF PHOSPHORIC AND BORIC ACIDS ON DIETHYLDIETHOXYSILOANE AND MIXTURES OF IT WITH TRIETHYLETHOXYSILOANE

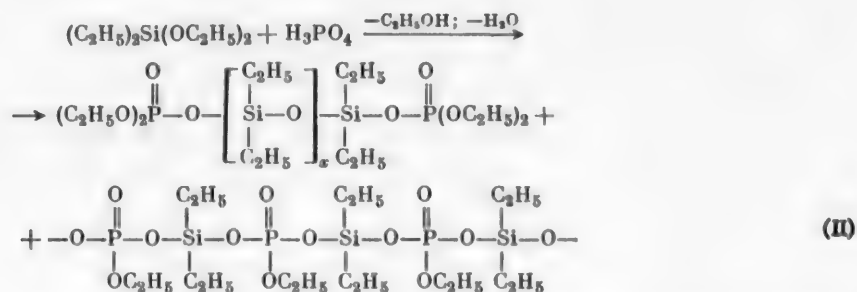
N. S. Leznov, L. A. Sabun and K. A. Andrianov

In a previous communication* it was shown that treatment of diethyldiethoxysilane and mixtures of it with triethylethoxysilane with sulfuric acid led to the formation of polydiethylsiloxanes of cyclic or linear structure with various fractional compositions, depending on the quantitative ratios of the reagents and the acid concentration.

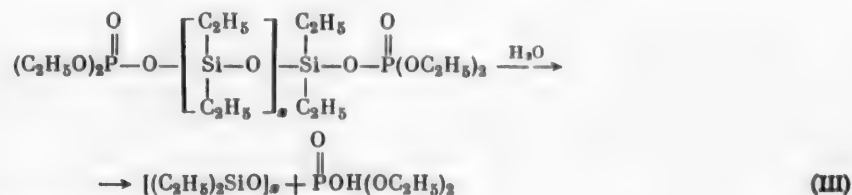
In the present communication, data are presented on the reactions of phosphoric and boric acids with ethylethoxysilanes. The investigation showed that as with sulfuric acid, the action of phosphoric acid on diethyldiethoxysilane at a molar ratio of the latter to acid of from 3 : 2 to 1 : 2 formed polydiethylsiloxanes, free from traces of linear polymers with ethoxy groups in the molecule, and acid ethyl esters of phosphoric acid. The neutral ester was not detected in the reaction products. In contrast to the reaction of diethyldiethoxysilane with sulfuric acid, which may be represented by scheme (I).



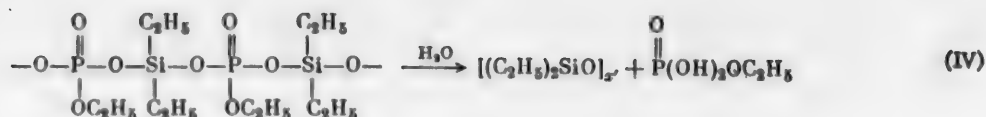
the reaction with phosphoric acid proceeds through the stage of the formation of polydiethylsiloxane phosphates, which are stable in the reaction medium, by scheme (II).



The reaction of water on the reaction product produces hydrolysis of the phosphates with the liberation of polydiethylsiloxanes and acid ethyl esters of phosphoric acid by schemes (III and IV).



* See J. Gen. Chem., 29, 1270 (1959).



Polydiethylsiloxane phosphates could not be isolated. In an attempt to distill the reaction mixture in high vacuum, after removal of the alcohol, decomposition began. The presence of polydiethylsiloxane phosphates was confirmed by the following indirect experimental data.

1. The reaction product contained a considerable amount of free alcohol which was removed by heating to 100° (15 mm) to give a highly viscous mass that was completely soluble in benzene. Since polydiethylsiloxanes are completely soluble in benzene and insoluble in alcohol and acid ethyl esters of phosphoric acid, which are insoluble in benzene, the homogeneity of the reaction product and its benzene solutions indicates the absence of free acid ethyl esters of phosphoric acid from it.

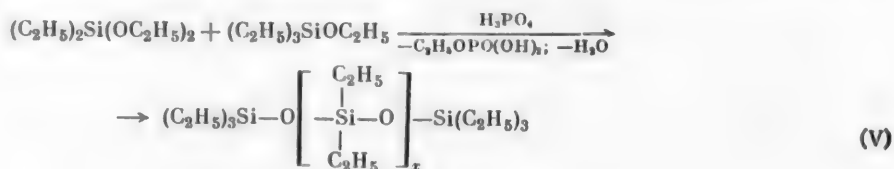
2. The action of water on the reaction product produced considerable heat evolution and after 2-3 minutes, the mixture clearly separated into a layer of polydiethylsiloxanes and one of an aqueous solution of acid ethyl esters of phosphoric acid. The viscosity of each of the layers formed was much lower than that of the original reaction product. These data indicate a hydrolysis process by schemes (III and IV).

3. Fractionation of the polydiethylsiloxanes showed that they contained no fraction with b. p. 185-250° (1 mm) at all. The undistillable residue, representing up to 60%, was an immobile mass of a resinous type with a viscosity of more than 2600 centistokes at 20°. [The polydiethylsiloxanes obtained with sulfuric acid contained 25-30% of a fraction with b. p. 185-250° (1 mm) and the viscosity of the distillation residues did not exceed 600-700 centistokes].

The data presented confirm our hypothesis on the presence of two forms of polydiethylsiloxane phosphate (scheme II) in the reaction product. On considering the hydrolysis process, it can be seen that on losing an acid ester of phosphoric acid, the polydiethylsiloxane phosphates (scheme III) already contain a polymeric grouping and further condensation of this leads to high-molecular undistillable polymers. Hydrolysis of polydiethylsiloxane phosphates (scheme IV) liberates separate polymer units, cyclization of which leads to low-boiling products.

Polydiethylsiloxanes, obtained in reaction of diethyldiethoxysilane with phosphoric acid, contained traces of linear polymers with hydroxyl groups on the terminal silicon atoms. The presence of the latter indicates that during hydrolysis of polydiethylsiloxane phosphates, cyclization of the polymers did not proceed to completion. Due to the water solubility of the low-molecular compounds containing hydroxyl groups in the molecule, without additional treatment of the aqueous solutions, the yield of polydiethylsiloxanes did not exceed 80-85%. The water-soluble compounds were isolated in the form of cyclic polydiethylsiloxanes by heating the aqueous solutions in the presence of sulfuric acid.

The action of phosphoric acid on a mixture of diethyldiethoxysilane and triethylethoxysilane (as with sulfuric acid) led to the formation of polydiethylsiloxanes, which largely contained linear polymers with triethylsilyl groups at the ends of the chain (Scheme V).



In this case the fractional composition of the polydiethylsiloxanes was similar to the composition obtained with sulfuric acid and was largely determined by the ratio of ethylethoxysilanes introduced into the reaction. The presence of monofunctional triethylsilyl derivatives in the reaction mixture completely or partially prevents the formation of polydiethylsiloxane phosphates (Scheme II), by blocking the terminal units of the growing

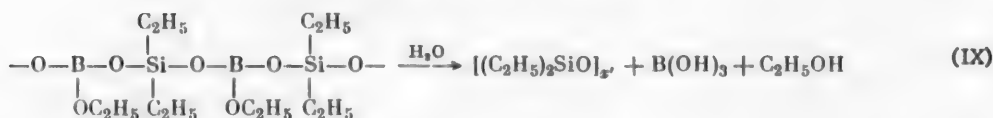
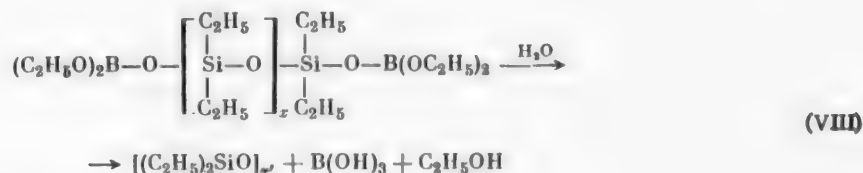
polymer chain with triethylsilyl groups; the latter also saturate the free valences of the terminal atoms of the chain on hydrolysis of polydiethylsiloxane phosphates (Schemes III and IV).

The action of boric acid on diethyldiethoxysilane was investigated at molar reagent ratios of 2 : 3 and 1 : 3. Heating 2 moles of boric acid with 3 moles of diethyldiethoxysilane to 90-100° led to the formation of triethyl borate, alcohol and a mixture of cyclic polydiethylsiloxanes, containing traces of linear polymers with ethoxyl groups at the terminal silicon atoms; the formation of the latter was not eliminated by increasing the duration of the reaction.

Cyclic polydiethylsiloxanes, free from traces of linear polymers, were obtained when a catalytic amount of sulfuric acid was introduced into the reaction mixture; the yield did not exceed 85%. The amount of triethyl borate reached 22% (when the same reaction was performed in a benzene medium with continuous removal of its vapor, the yield was 40%). Since the low yield of triethyl borate is caused by hydrolysis with water formed by the reaction of scheme (VI), the possibility of a reaction according to equation (VII) can be proposed.



Experimental data showed that at the given ratio, the yield of polydiethylsiloxanes remained unchanged and the amount of triethyl borate reached 70%. Free boric acid was not detected in the reaction product; when the latter was treated with water, the liberation of boric acid began. The results of the investigation and also the complete analogy of the properties of the products from reactions with boric and phosphoric acids with diethyldiethoxysilane make it possible to postulate a formation process for polydiethylsiloxanes in reactions with boric acid, proceeding through the stage of polydiethylsiloxane borates, stable in the reaction mixture; hydrolysis of these compounds with water leads to the formation of free polydiethylsiloxanes by schemes (VIII and IX).



The fractional compositions of the polymers obtained in reactions with boric and phosphoric acids were analogous. There were considerable amounts of fractions with b. p. 100-150° (1 mm) and highly viscous residues not distilling up to 250° (1 mm), while fractions boiling above 150° (1 mm) were completely absent, which agrees with schemes (VIII and IX), considered above for the case of the hydrolysis of polydiethylsiloxane phosphates.

EXPERIMENTAL

1. Action of phosphoric acid on diethyldiethoxysilane. Phosphoric acid was added to diethyldiethoxysilane with stirring over a period of 10-15 minutes. The temperature of the mixture rose to 70-75°. After being kept for 1-3 hours, the reaction product was cooled to room temperature, diluted with benzene and poured with stirring into 2-3 times the volume of water and ice. The benzene layer liberated was washed with water, 1% sodium carbonate solution (until neutral to phenolphthalein) and again with water until neutral and dried over calcium chloride. After removal of the benzene by heating to 130-140° (50 mm), the residue was

fractionated. Table 1 shows data of certain experiments characterizing the yield and chemical and fractional composition of polydiethylsiloxanes in relation to the quantitative ratios of the reagents and the acid concentration.

TABLE 1

Reaction of Phosphoric Acid with Diethyldiethoxysilane

Experiment No.	Reagents taken			Temperature	Duration of experiment (in hr.)	Yield of polydiethylsiloxanes (%)	Characteristics of polydiethylsiloxanes				
	diethyldiethoxysilane (in moles)	phosphoric acid					boiling point (1 mm)	yield (in %)		content (in %)	
		(in moles)	conc. (in %)					fraction	undistillable residue	OC ₂ H ₅	Si...
1	1	1	99.2	50°	1	86	105—180°	70	30	0.0	27.00
2	1.5	1	99.2	50	2	88	102—165	63	37	1.18	26.49
3	1.5	1	99.2	75	3	87	100—190	65	35	0.0	27.12
4*	1.5	0.5	99.2	100	10	70	98—250	66	34	0.0	26.98
5	1	2	80	50	1	88	110—125	35	65	0.0	27.37
6	1	1	80	50	1	87	110—195	70	30	0.0	26.85
7	1.5	1	80	75	3	87	—	—	—	1.74	—

*The undistillable residues were immobile masses.

**In experiment 4, 84 g of aqueous alcohol and 36 g of unchanged diethyldiethoxysilane were first distilled from the reaction mixture.

***The calculated silicon content of a unit of the cyclic polymer was 27.45%.

TABLE 2

Reaction of Phosphoric Acid with a Mixture of Diethyldiethoxysilane and Triethylethoxysilane and Triethylethoxysilane (In all the experiments 1 mole of triethylethoxysilane was used, the duration was 2 hours and the temperature, 75°)

Expt. No.	Reagent taken			Yield of polydiethylsiloxanes (in %)	Characteristics of polydiethylsiloxanes				
	diethyldiethoxysilane (in moles)	phosphoric acid			b. p. (1 mm)	yield (in %)		viscosity of residue at 20° (in centistokes)	Si content (in %)
		(in moles)	conc. (in %)			fraction	undistillable residue		
1	1	2	80	89	75—250°	82	8	158	26.02
2	2	3.33	80	91	76—250	88	12	169	26.11
3	2	3.33	99.4	91	76—250	89	11	189	25.98
4	3	4.66	99.4	93	86—250	78	22	174	26.23

*The OC₂H₅ group was not detected.

**The silicon contents of the fractions were different. Data are presented for fractions with b. p. 185—250°. The calculated silicon content of octaethyltrisiloxane was 24.16% and for octadecaethyloctasiloxane, 26.12%.

The main aqueous layer after removal of the benzene solution was neutralized with saturated sodium bicarbonate solutions and evaporated at 8 mm until crystallization began. The mixture was cooled to 5° and

TABLE 3

Reaction of Boric Acid with Diethyldiethoxysilane

Expt. No.	Reagent taken			Temperature	Duration of reaction (in hours)	Polydiethoxanes obtained (in %)	Characteristics of polydiethylsiloxanes				Boric acid liberated from volatile reaction products		Polydiethylsiloxanes liberated from aqueous solution				
	diethyl-diethoxy-silane (in moles)	boric acid (in moles)	sulfuric acid (d 1.84) (in g)				b. p. (1 mm)	yield (in %)	content (in %)	yield (in g)	calc. on triethyl borate (in %)	yield (in %)	b. p. (in mm)	Si content (in %)			
															undistillable residue fraction	OC ₂ H ₅	Si
1	1.5	1	—	90—95°	3	59	100—125°	35	65	5.58	25.59	—	—	—	—		
2	1.5	1	0.6	90—95	3	73	105—135	52	48	0.0	27.65	13	21	93—148°	27.49		
3	1.5	1	0.9	75—80	6	69	103—156	54	46	0.0	27.28	26	43	97—139	27.34		
4	1.5	0.5	0.6	80—90	10	70	85—250	73	27	5.89	—	21	69	—	—		

Footnote. 1. The undistillable residues were immobile masses. 2. Experiment 3 was in a benzene medium.

the precipitate of silvery-white crystals of the sodium salts of acid ethyl esters of phosphoric acid filtered off, washed with benzene and a small amount of alcohol and dried to constant weight at 55-60°.

Found hydrolysis number 407.0, 406.5.

$C_4H_{10}O_4PNa$. Calculated hydrolysis number

636.4. $C_2H_5O_4PNa_2$. Calculated hydrolysis number 329.0.

2. Action of phosphoric acid on a mixture of diethyldiethoxysilane and triethylethoxysilane. The experiments were performed by the procedure described in experiment 1. The data from some experiments are presented in Table 2.

3. Action of boric acid on diethyldiethoxysilane. A mixture of diethyldiethoxysilane and boric acid was stirred and heated to 90-95° in a flask connected to a distillation condenser. During the reaction, a mixture of alcohol and triethyl borate distilled over. At the end of the reaction, vacuum (8-12 mm) was applied and the temperature of the mixture raised to 130-140°. When cooled to room temperature, the residue, which formed a viscous resinous mass, was dissolved in benzene and shaken with 2-3 times its volume of water; the mixture evolved heat, and boric acid was liberated and passed into the aqueous solution. After 20-30 minutes, the aqueous layer was separated and the benzene layer washed with water, neutralized (to phenolphthalein) with 1% sodium carbonate solution and again washed with water to a neutral reaction. After drying over calcium chloride, the benzene was removed and the residue fractionated at 1 mm. The triethyl borate, which distilled over during the reaction together with alcohol, was hydrolyzed with water, with subsequent evaporation and drying to constant weight in vacuum. The aqueous solutions, separated from the benzene layer, were heated to 80° with sulfuric acid for 2-3 hours. The layer of polydiethoxysilanes which separated was washed to a neutral reaction, dried with calcium chloride and fractionated in vacuum. Data from some of the experiments carried out by the procedure described above are presented in Table 3.

SUMMARY

An investigation was made of the reactions of diethyldiethoxysilane with phosphoric and boric acids. The possibility of preparing polydiethoxysilane, free from traces of polymers containing ethoxyl groups in their molecules, was established and an investigation was made of their fractional composition.

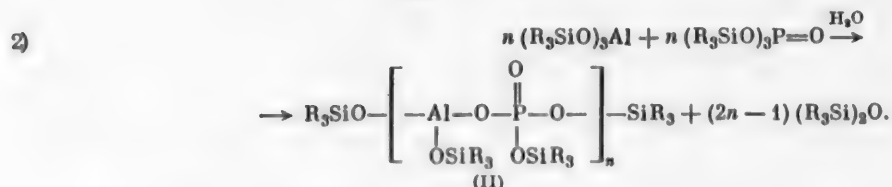
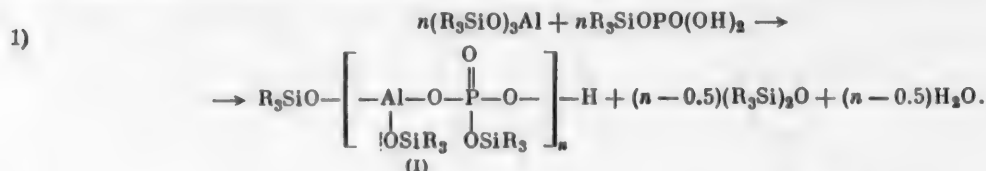
Received March 10, 1958

SYNTHESIS OF POLYMERS WITH INORGANIC CHAINS IN THE MOLECULES

1. POLYORGANOSILOXYPHOSPHORALUMOXANES

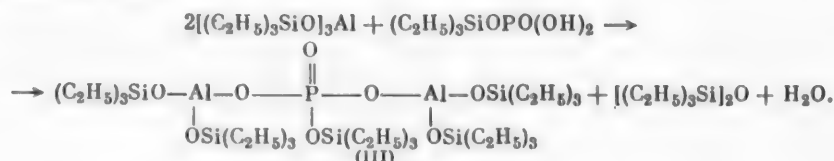
K. A. Andrianov, A. A. Zhdanov, and A. A. Kazakova

Polymeric compounds with inorganic chains in the molecules, containing aluminum, oxygen and phosphorus in the chains, were described in a previous communication [1]. Further investigations by us showed that polyalkylsiloxyaluminophosphates were formed by the polycondensation of tris-(trialkylsiloxy)-aluminum with phosphorosilicoorganic compounds by the following reaction schemes.



The character of the polymers formed and their properties depended on the nature of the organic radical in the framing trialkylsiloxane groups. The condensation of tris-(triethylsiloxy)-aluminum with triethylsiloxyphosphinic acid or tris-(triethylsilyl)-phosphate at 200-220° yielded polymers which were soluble in organic solvents and which were converted into an infusible, insoluble state by further heating. Condensation of tris-(trimethylsiloxy)-aluminum with trimethylsiloxyphosphinic acid or tris-(trimethylsilyl)phosphate under the same conditions proceeded very rapidly with the formation of solid infusible, insoluble polymers, probably with a three-dimensional structure.

As follows from the reaction schemes presented above, the formation of the polymers was accompanied by the liberation of hexaalkyldisiloxane and water. To confirm the reaction schemes presented above, experiments were carried out on the condensation of 2 moles of tris-(triethylsiloxy)-aluminum with 1 mole of triethylsiloxyphosphinic acid. The excess tris-(triethylsiloxy)-phosphinic acid was taken so as to stop the growth of the polymer chains and to obtain low-molecular products. As a result of these experiments we obtained the low-molecular condensation product (III) and isolated hexaethyldisiloxane and water in amounts corresponding to the reaction equation below.



The condensation product (III) was a clear, viscous liquid, which was readily soluble in alcohol, benzene and toluene. The analysis of the substance corresponded to the compound given in the equation.

In the condensation of tris-(triethylsiloxy)-aluminum with triethylsiloxyphosphinic acid in a molar ratio, solid polymers were obtained.

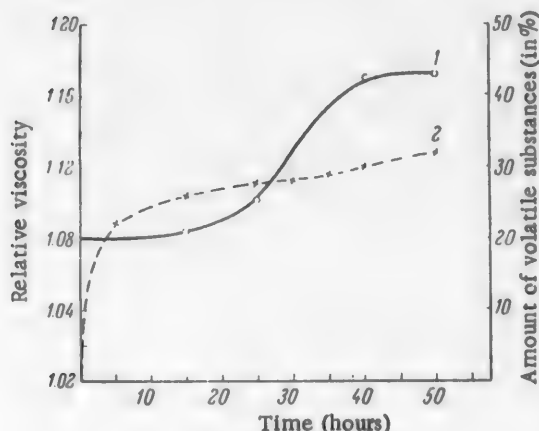


Fig. 1. Explanation in text.

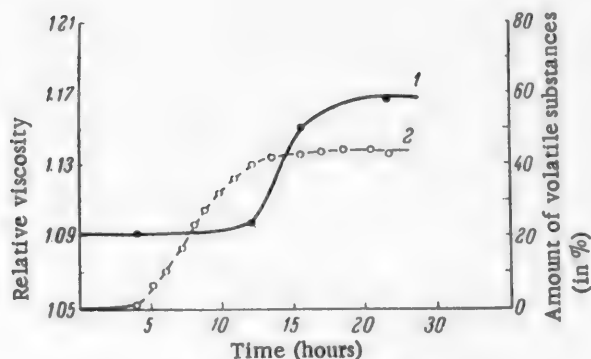


Fig. 2. Explanation in text.

The viscosity of a 10% solution of the polymer in toluene, observed during the course of the reaction, and determination of the amounts of hexaethylsiloxane and water liberated showed that there was a connection between the viscosity of the polymer and the amount of low-molecular substances liberated. Figure 1 shows that in the reaction of tris-(triethylsiloxy)-aluminum with triethylsiloxyphosphinic acid, the amount of low-molecular products liberated increased regularly (curve 2) with an increase in the viscosity of the polymer formed (curve 1), which indicates that the condensation reaction proceeds stepwise.

Figure 2 shows the dependence of the viscosity of a 10% solution of polymer in toluene (curve 1) and the amount of hexaethylsiloxane and water liberated (curve 2) on time of condensation of tris-(triethylsiloxy)-aluminum with tris-(triethylsilyl)-phosphate with moist air passed through. Here also, a gradual growth in the polymer viscosity was observed with a simultaneous growth in the total amount of hexaethylsiloxane and water liberated. When tris-(triethylsiloxy)-aluminum was heated (200-220°) with triethylsiloxyphosphinic acid for 40 hours, without the passage of moist air, the evolution of hexaethylsiloxane was not detected and the viscosity of the mixture of products remained practically without change. These experiments show that the introduction of water is necessary for the condensation. The reaction probably proceeds by Scheme 2.

EXPERIMENTAL

In the work we used the following products, obtained by procedures described previously: tris-(triethylsiloxy)-aluminum [2] (% Si 19.41; Al 6.97; calc. Si 20.0; Al 6.41), tris-(trimethylsiloxy)-aluminum [1] (% Si 27.20; Al 9.54; calc. Si 28.58; Al 9.16), tris-(triethylsilyl)-phosphate [3], n_D^{20} 1.4462, b. p. 156-163° (5 mm) (n_D^{20} 1.4457, b. p. 200.5° at 11 mm [3]) (% Si 20.42; P 5.64; calc. Si 19.1; P 7.03), tris-(trimethylsilyl)-phosphate [3], n_D^{20} 1.4095, b. p. 77° at 4 mm (n_D^{20} 1.4090, b. p. 97° at 6 mm [3]) (% Si 26.72; P 9.85; calc. Si 26.62; P 9.85), triethylsiloxyphosphinic acid [4] (% Si 12.57; P 13.86; OH 17.25; calc. Si 13.20; P 14.50; OH 16.05), and trimethylsiloxyphosphinic acid [4], m. p. 66.5° (% Si 15.06; P 17.21; OH 20.42; calc. Si 16.48; P 18.21; OH 19.99).

Condensation of tris-(triethylsiloxy)-aluminum with triethylsiloxyphosphinic acid. Into a ~50 ml, two-necked flask, fitted with a thermometer and an outlet tube, connected to a trap cooled in liquid nitrogen, was placed 4.2 g (0.01 mole) of tris-(triethylsiloxy)-aluminum and 2.1 g (0.01 mole) of triethylsiloxyphosphinic acid. The temperature in the reaction flask was slowly raised to 200-220° and kept in this range until the evolution of low-molecular substances practically ceased. The viscosity of the condensation products as a 10%

toluene solution was determined in an Ostwald viscometer at 20° (Fig. 1). The solution in the trap was a mixture of water and an organic substance with n_D^{20} 1.4332 and b. p. 220–230°, which corresponds to hexaethyldisiloxane (n_D^{20} 1.4323 and b. p. 230°). The condensation product was a polymer which was soluble in toluene, benzene and alcohol. The yield was 3.5 g (94%).

Found %: C 35.09, 35.74; H 8.42, 8.74; Al 9.36, 9.88; Si 16.41, 16.60; P 8.83, 9.47. M 5600 (determined ebullioscopically [5]). $C_{174}H_{430}O_{71}Al_{14}Si_{28}P_{14}$. Calculated %: C 39.50; H 8.30; Al 7.14; Si 15.38; P 8.19. M 5290.

The calculations were for a polymer of formula (I), $R = C_2H_5$, $n = 14$.

Interaction of tris-(triethylsiloxy)-aluminum with triethylsiloxyphosphinic acid. Into the apparatus described previously was placed 8.4 g (0.02 mole) of tris-(triethylsiloxy)-aluminum and 2.1 g (0.01 mole) of triethylsiloxyphosphinic acid. The temperature in the reaction flask was very slowly (4 hours) raised to 220° and the reaction was kept at $220 \pm 5^\circ$ for 15 hours. The low-molecular products liberated (2.95 g) were a mixture of water and hexaethyldisiloxane (n_D^{20} 1.4350 and b. p. 220–230°). We obtained 7.55 g of a viscous, light-yellow liquid (III).

Found %: C 44.42, 44.55; H 8.44, 8.86; Al 7.26, 7.18; Si 18.46, 18.64; P 3.55, 3.58. M 783. $C_{90}H_{78}O_9Al_2Si_6P$. Calculated %: C 45.67; H 9.58; Al 6.85; Si 17.86; P 3.92. M 789.

Condensation of tris-(triethylsiloxy)-aluminum with tris-(triethylsilyl)-phosphate. Into a two-necked flask, fitted with a thermometer, a capillary for the introduction of air and an outlet tube connected to a trap cooled in liquid nitrogen, was placed 4.2 g (0.01 mole) of tris-(triethylsiloxy)-aluminum and 4.4 g (0.01 mole) of tris-(triethylsilyl)-phosphate. The reaction was performed at 200–220° for 21.5 hours with moist air passed through the reaction mixture. As the reaction proceeded, the viscosity of a 10% toluene solution of the condensation products was determined with an Ostwald viscometer at 20° (Fig. 2). The low-molecular products were a mixture of water and hexaethyldisiloxane.

We isolated clear, yellow resinous substances, which were solid at 20° (but not brittle) and soluble in toluene, benzene and alcohol.

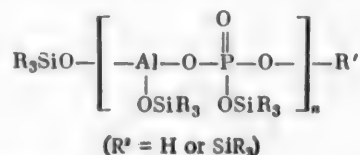
Found %: C 39.51, 40.05; H 8.04, 8.17; Al 10.69, 11.13; Si 17.89, 17.99; P 7.46, 7.57. M 1730. $C_{88}H_{150}O_{21}Al_4Si_{10}P_4$. Calculated %: C 41.70; H 8.70; Al 6.25; Si 16.25; P 7.18. M 1726.

The calculations were for a polymer for formula (II), $R = C_2H_5$, $n = 4$.

SUMMARY

1. The condensation of 2 moles of tris-(triethylsiloxy)-aluminum with 1 mole of triethylsiloxyphosphinic acid yielded a low-molecular condensation product.

2. The condensation of equimolecular amounts of tris-(triethylsiloxy)-aluminum with triethylsiloxyphosphinic acid or tris-(triethylsilyl)-phosphate gave polymeric products of the composition



which were soluble in toluene, alcohol and benzene.

3. The condensation of tris-(trimethylsiloxy)-aluminum with trimethylsiloxyphosphinic acid or tris-(trimethylsilyl)-phosphate gave solid, powdery, infusible products, which were insoluble in organic solvents.

LITERATURE CITED

[1] K. A. Andrianov, A. A. Zhdanov, and A. A. Kazakova, Bull. Acad. Sci. USSR, Div. Chem. Sci. 1959, 466.*

*Original Russian pagination. See C.B. Translation.

- [2] K. A. Andrianov, A. A. Zhdanov, and S. A. Pavlov, *Proc. Acad. Sci. USSR*, 102, 85 (1955).
- [3] M. G. Voronkov, *J. Gen. Chem.* 25, 469 (1955).*
- [4] K. A. Andrianov, B. N. Rutovskii, and A. A. Kazakova, *J. Gen. Chem.* 26, 267 (1956).*
- [5] C. A. Smith, *Trans. Faraday Soc.*, 52, 402 (1956).

Received March 15, 1958

* Original Russian pagination. See C. B. Translation.

THE PROCESS OF POLYAMIDE RESIN FORMATION

IX. A CONTRIBUTION ON THE ALKALINE POLYMERIZATION OF ϵ -CAPROLACTAM

A. S. Shpital'nyi and M. A. Shpital'nyi

Leningrad Textile Institute

In previous work devoted to the alkaline polymerization of caprolactam [1], it was shown that the reaction of caprolactam with sodium hydroxide at 270-280° formed the sodium salt of aminocaproic acid and that the latter was capable of initiating the formation of polymer if it were added in small amounts to caprolactam. In the present work we consider schemes for obtaining polymer from caprolactam in the presence of metallic sodium and certain peculiarities of the alkaline polymerization, connecting this process with other reactions leading to the formation of polymer.

According to literature data, polymers from caprolactam with metallic sodium added [2] or sodium hydroxide added [3] are obtained by the same scheme and therefore have the same structure.



On determining the terminal groups by titration of polymer samples, obtained from caprolactam in the presence of sodium hydroxide, Gril' came to the conclusion that NH_2 and carboxyl groups were at the ends of the macromolecules, as in polyamides obtained by the usual method. He explained the appearance of two terminal groups by the capacity of the lactam ring, even in the solid polymer, for hydrolysis in contact with water.

Considering the stability of the lactam ring to the action of water and dilute alkali solutions, on the basis of results of previous work [1], we consider that the presence of the two terminal groups would be explained more correctly by the participation of the salt of aminocaproic acid in the reaction.

In the preparation of polyamide from caprolactam and metallic sodium, the salt of aminocaproic acid was not formed as an intermediate compound. Therefore, it was interesting to determine the character of the terminal groups of this polymer, the more so as no information on this problem could be found in the literature. Hanford, who was working in this field, did not determine the end groups of the polymers. We established that regardless of the nature of the alkaline agent, all the polymers behaved in analysis as if they possessed amine and carboxyl groups.

In connection with this it should be noted that if the structure of one terminal group of the macromolecule had the form $(\text{CH}_2)_5 \begin{array}{c} \text{C} - \text{N} - (\text{CH}_2)_5 \dots \\ || \quad | \\ \text{O} \quad \text{H} \end{array}$, then one of the two nitrogens at the carbon would possess

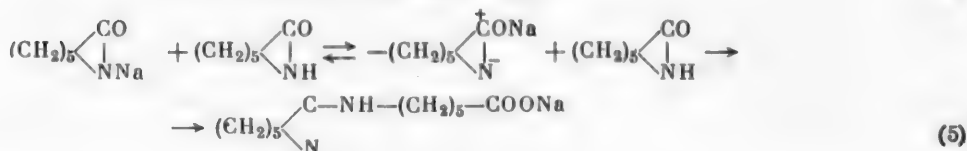
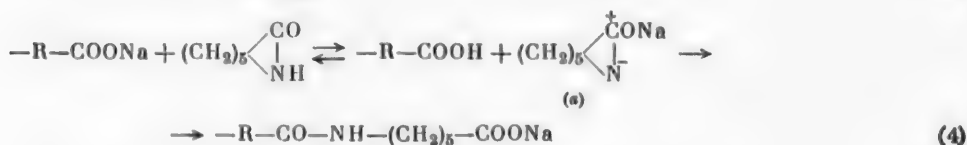
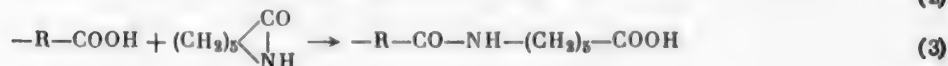
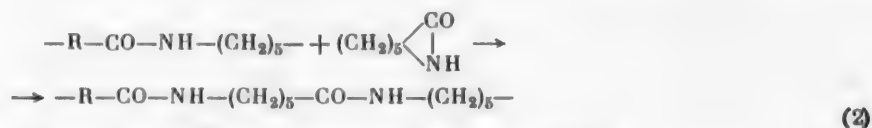
basic properties and titrate like an NH_2 group. Therefore, the capacity for titration by standard alkali and acid solutions in alcohol is no proof of the presence of carboxyl and NH_2 groups in the macromolecule since a polymer having a lactam ring and a carboxyl group as the terminal groups would titrate in the same way. The ideas presented were confirmed by experiment. The reaction of caprolactam with metallic sodium in a molecular ratio of 2 : 1 at 280° gave a water-soluble product, which after purification from sodium appeared

as a plastic resinous mass, that in appearance had nothing in common with the open-chain dimers and trimers (etc.) of aminocaproic acid described [4]. This mass was converted into aminocaproic acid by acid hydrolysis. The introduction of alkyl groups at the nitrogen or oxygen of caprolactam led to the formation of liquid products. The presence of a lactam ring in the molecules of the dimers and trimers would make these compounds similar in structure to N- and O-substituted lactams and lower their melting points. Consequently, the plastic products isolated were low-molecular polymers containing a lactam ring in their structure.

It was also found that the size of the polymer macromolecule could be regulated to some extent by the amounts of sodium, as by the amounts of sodium hydroxide. In the case of NaOH, this capacity was noted by Gril'. In contrast to Gril', by means of appropriate amounts of NaOH, we obtained polymers of extremely low molecular weight (below 2000). These experiments without doubt indicated the stepwise character of the conversions studied, exactly the same as we observed in the normal process for the formation of polyamide from caprolactam [5].

The analogous course of the reaction in the diverse processes leading to the conversion of caprolactam to polyamide is evidently the result of the interaction of related functional groups and must be reflected in schemes for the formation of polyamide polymers. As regards these schemes, it should be noted that most investigators think it possible to treat the conversion of caprolactam into polymer in the presence of alkaline compounds or alkali metals as processes of the polymerization type. Formally this type of treatment is reasonable, since these processes are not accompanied by the liberation of simpler molecules (water, alcohol, etc.) and the structural group of the macromolecule forming the polymer has the same composition as the monomer.

As regards the mechanism of the polymerization considered, there is no single opinion; some call it ionic and consider that at least one terminal group participates in the conversion (Gril'); others think that the participation of the terminal groups is not obligatory (Vikhterle). Therefore, without stopping to discuss literature material devoted to this problem, we consider it worthwhile to point out the possibility of using the mechanism of the transamination process, studied by B. A. Porai-Koshits, et al. [6], for explaining any conversion of caprolactam into polymer. Let us consider the following conversions (schemes 2-5):

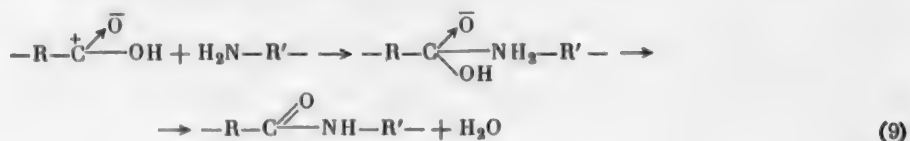


The complex functions, containing the groups $-CO$, $-NH$, $-OH$, $>N$ and others, which have different electron-donor or electron-acceptor activities, react together.

Scheme 4 represents the conversion of caprolactam into polymer in the presence of NaOH. Above, it has already been pointed out that according to experimental data, the reaction product of caprolactam and NaOH (with excess alkali and at 280°) is the sodium salt of aminocaproic acid. The latter, when reacted with caprolactam, must in the first instance promote the reaction of caprolactam shown in scheme 4 to form compound (a) with extremely active functional groups, which is capable of reacting vigorously with both carboxyl groups and lactam.

Thus, any method of converting caprolactam into polymer can be explained by the transamination reaction proposed by B. A. Porai-Koshits et al.

It is quite obvious that reactions 4 and 5, in which the most active functional groups participate, will proceed at the greatest rate. According to Vikhterle, the rate of the process in alkaline polymerization is also explained by the activity of the anion of the lactam salt. However, assuming terminal groups to be absent from the reaction mass, he considered that the active anion only reacted with $-\text{CO}-\text{NH}-$ group. After all that has been said, it does not require special explanations to add the preparation of nylon resin to processes whose mechanism can be represented by the reactions listed above.



EXPERIMENTAL

Caprolactam and metallic sodium were placed in ampules which were pumped out (3 mm) and sealed. When NaOH was used instead of metallic sodium, it was ground with the caprolactam before loading and when the ampule had been pumped out, it was heated for some time on a water bath before sealing. Ampules with

Amount of caprolactam (in g)	Am't of alkaline agent (in g)		Molecular ratio of caprolactam : alkaline agent	Molecular weight	
	metallic Na	NaOH		determined from carboxyl groups	determined from amine groups
2	0.07	—	5.8 : 1	1700	1250
4	0.07	—	11.6 : 1	5000	—
5.65	0.02	—	57 : 1	10000	8333
2.26	—	0.16	5 : 1	1000	1000
2.26	—	0.08	10 : 1	1600	1400
3.39	—	0.07	17 : 1	2000	—
2.26	—	0.016	50 : 1	4350	4350

the reaction mixture containing metallic sodium were kept at 280° for 1 hour and with NaOH, for 3 hours. The ampules were then cooled and smashed and the resin broken up and washed for a long time with hot water until traces of alkali had been removed completely. The washed resin was dried and analyzed [7]. The analysis results are presented in the table.

11.3 g of caprolactam and 1.15 g of metallic sodium were placed in a steel tube whose top was fitted with a Hofer tap. The tube was evacuated and kept for 2 hours at 270–280°. The resin was dissolved in water (100 ml); the solution was neutralized to methyl orange with dilute sulfuric acid. The solution was then evaporated in a porcelain dish on a water bath. The dry residue was divided into two parts; one part was treated with ethyl alcohol and the second with methyl ether. Ether was added to the alcohol extracts until the solution became strongly turbid. In the first case a tarry mass was precipitated, in the second, a sticky powder. When the molecular weight was determined from the number of terminal carboxyl groups, for both products it was found to be equal to 300. The molecular weight, determined from the number of terminal NH_2 groups, was twice as great and equalled 600. When the resin, obtained from the alcohol extract, was hydrolyzed with 10% sulfuric acid [8], we obtained crystals which did not depress the melting point of aminocaproic acid.

Thus, the different classification of methods of preparing polyamide polymers, depending on the nature of the starting materials and the peculiarities of the methods themselves, has a definite arbitrary character since it is not connected with different conversion mechanisms.

SUMMARY

1. It was established that the size of the macromolecule of the polyamide from caprolactam can be regulated by the amounts of metallic sodium added, in the same way as by the amounts of NaOH.
2. Considerations are presented showing that one of the terminal groups of the polyamide macromolecule, obtained from caprolactam by means of metallic sodium, is a lactam ring.
3. On the basis of the transamination reaction mechanism proposed by B. A. Porai-Koshits, schemes are presented showing that the mechanisms of the conversion of caprolactam and diamines and dicarboxylic acids into polyamide polymers do not differ in principle.

LITERATURE CITED

- [1] A. S. Shpital'nyi and N. S. Yablochnik, *J. Gen. Chem.* 28, 3282 (1958).*
- [2] F. W. Hanford and R. M. Joice, *J. Polymer. Sci.*, 3, 167 (1948).
- [3] V. Gril'. Stenograph of Conference on the Scientific and Technical Cooperation of the USSR and the Peoples Democracies in the Field of the Production of Chemical Fibers, State Sci. Tech. Press of Min. of Manufactured Consumer Goods, 103 (1956).
- [4] G. M. Van der Want, H. Peters, and P. Inklaar, *Rec. trav. chim.* 71, 379 (1952).
- [5] A. S. Shpital'nyi, K. E. Perepelkin, and E. A. Meos, *J. Gen. Chem.* 24, 447 (1954).*
- [6] B. A. Porai-Koshits, O. F. Ginzburg, and L. S. Efros, *J. Gen. Chem.*, 17, 1768 (1947).
- [7] J. E. Waltz and G. W. Taylor, *Anal. Chem.* 19, 448 (1947).
- [8] R. Benson and T. Cairus, *J. Am. Chem. Soc.* 70, 2115 (1948).

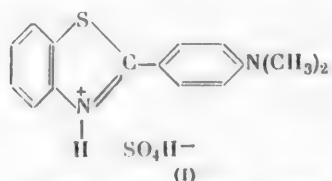
Received February 24, 1958

*Original Russian pagination. See C.B. Translation.

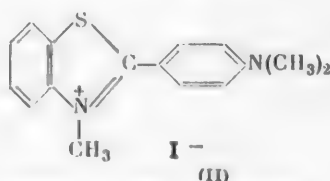
STERIC HINDRANCE IN QUATERNARY SALTS OF 2-ARYLBENZ- THIAZOLES, 2-ARYLBENZIMIDAZOLES AND 2-ARYLPYRIDINES

A. I. Kiprianov and V. A. Shrulovich

In our previous work [1] it was shown that in quaternary salts of 2-p-dimethylaminophenylbenzthiazoles and 2-p-dimethylaminophenylbenzselenazole, the benzene nucleus is not coplanar with the benzthiazole or the benzselenazole nucleus due to steric hindrance. This conclusion was arrived at on the basis of a comparison of the absorption maxima of these quaternary salts in alcohol solution with the absorption maxima of the sulfates of the same bases, for example, a comparison of the maxima of the salts (I) and (II).



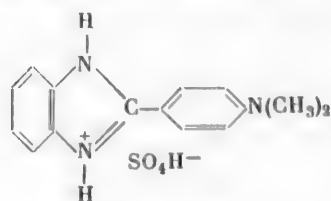
Absorption maximum 432 mμ.



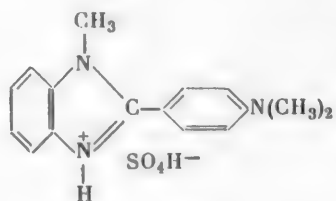
Absorption maximum 420 mμ.

Despite the general rule, here, in going from the simple salt to the quaternary one there is a shift in the absorption band, not into the long wavelength, but into the short wavelength part of the spectrum.

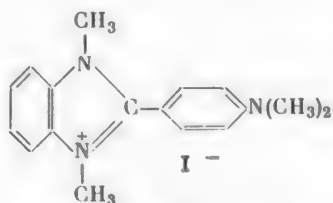
Now we can supplement the observations presented in the previous article by data on the light absorption of salts of 2-p-dimethylaminophenylbenzimidazoles. Here there is the possibility of comparing the absorption of not two, but three salts - (III), (IV) and (V).



Absorption maximum 369 mμ.



Absorption maximum 363 mμ.



Absorption maximum 343 mμ.

On the example of these salts, we observed the same phenomenon as with salts (I) and (II). The introduction of alkyls at the nitrogen atom of the heterocycle produced a shift in the absorption band towards the shortwave part of the spectrum, to the smallest extent in salt (IV) and particularly strongly in salt (V). This indicates disruption of the coplanarity of the nuclei as a result of steric hindrance.

It is well known that disruption of the coplanarity of the nuclei in molecules of aromatic compounds produces not only a shift in the absorption band towards shorter wavelengths, but also a decrease in the absorption intensity [2]. It is difficult to compare the absorption intensities of simple and quaternary salts of 2-dimethylaminophenyl derivatives of nitrogen heterocycles, since in the formation of simple salts, proton may add not only to the nitrogen atom of the ring, but also to the dimethylamino group. Therefore, we decided to extend the spectral measurements on salts of 2-aryl derivatives of nitrogen heterocycles not containing amino groups. With a sufficient excess of acid (we used sulfuric acid) the alcoholysis of such salts in alcohol solutions may be suppressed and not only the absorption maximum of the salt measured, but also its molecular extinction.

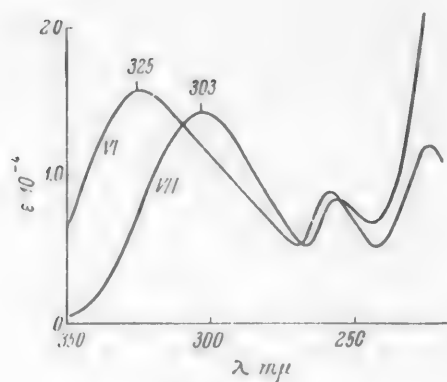


Fig. 1.

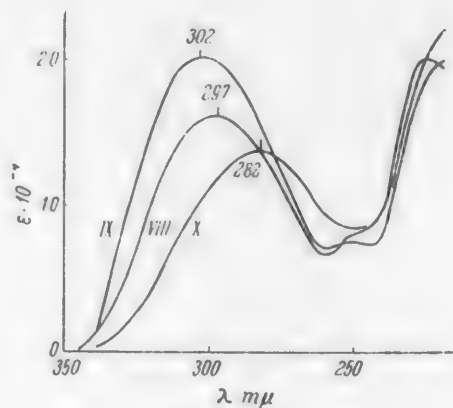


Fig. 2.

We determined the absorption spectra in alcohol solution of several 2-arylbenzthiazoles, 2-arylbenzimidazoles, 2- and 4-phenylpyridines and 2-phenylbenzoxazole, their sulfates (alcohol solutions of the bases with sulfuric acid added) and quaternary salts. A comparison of the absorption curves of the sulfates and quaternary salts showed that in all cases besides 4-phenylpyridine, the absorption maxima of the quaternary salts were shifted towards the shortwave region of the spectrum and the intensity reduced.

We should note here yet another consequence of the disruption of coplanarity in quaternary salts of 2-aryl-substituted nitrogen heterocycles. The bulk of these salts do not fluoresce under an ultraviolet lamp, while the corresponding sulfates fluoresce more or less brightly. The extinction of fluorescence as a result of disruption of the coplanarity of the nuclei in a molecule has already been reported [3].

Among benzthiazole derivatives, we investigated 2-phenylbenzthiazole, 2-p-tolylbenzthiazole and 2-o-tolylbenzthiazole, their sulfates and their methiodides or methylperchlorates. 2-Arylbenzthiazoles are very weak bases and therefore, to suppress the alcoholysis of their sulfates in alcohol solution, the absorption curves were measured in the presence of large amounts of sulfuric acid (up to 10 g per 100 ml of solution). By special experiments it was established that the absorption curves of quaternary salts in alcohol solutions of sulfuric acid of such concentrations were not essentially changed. Figure 1 shows the absorption curves of the sulfate (VI) and the methiodide (VII) of 2-phenylbenzthiazole. Going from the sulfate of 2-phenylbenzthiazole to the methiodide reduced the absorption intensity and shifted the longwave absorption maximum by more than 20 mμ towards shorter wavelengths. The same changes were also undergone by the weaker shortwave band, but to a lesser extent. The same was observed in the absorption spectra of the sulfate and methylperchlorate of 2-p-tolylbenzthiazole, whose bands are slightly more intense and lie closer to the visible part of the spectrum.

In the case of 2-o-tolylbenzthiazole, the methyl in the ortho position prevents coplanarity of the phenyl and thiazole nuclei, even in the molecule of the base. Figure 2 shows the absorption spectra of the three bases, 2-phenylbenzthiazole (VIII), 2-p-tolylbenzthiazole (IX) and 2-o-tolylbenzthiazole (X). We see that the methyl group in the para position increases the intensity of the absorption band and has little effect on the position of the maximum, while the methyl in the ortho position sharply lowers the intensity and shifts the maximum towards shorter wavelengths by 15 m μ .

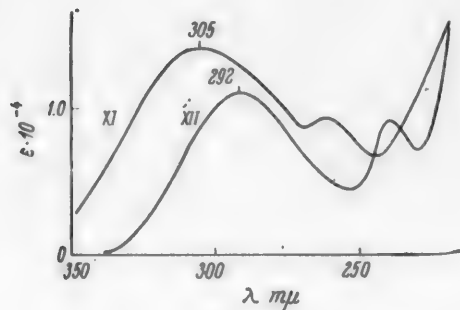


Fig. 3.

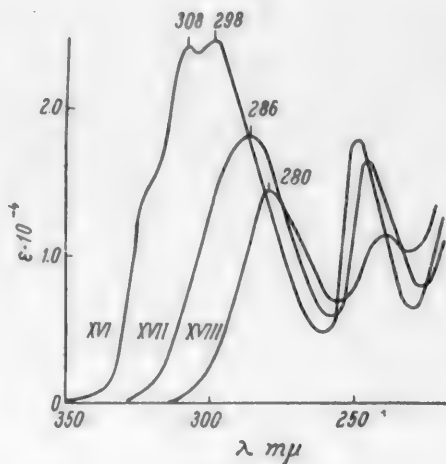
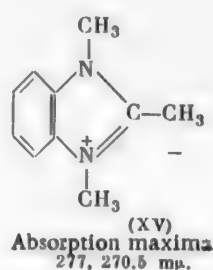
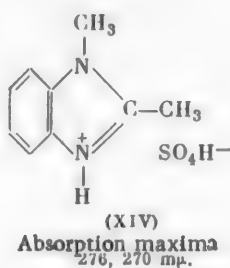
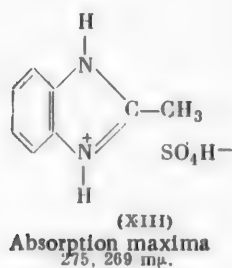


Fig. 4.

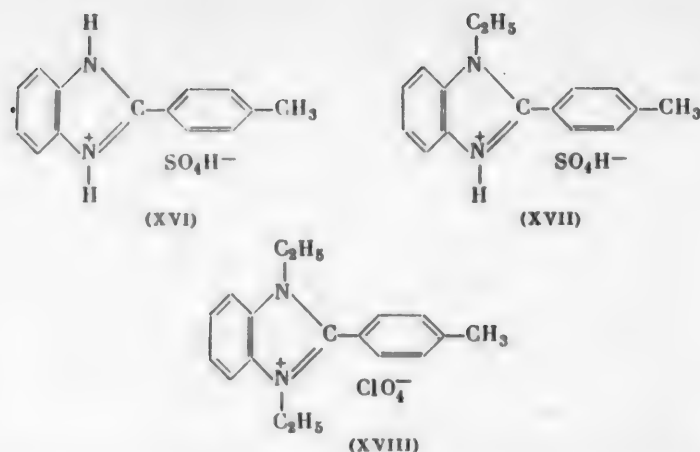
Figure 3 shows the absorption curves of the sulfate (XI) and the methylperchlorate (XII) of 2-o-tolylbenzthiazole. The absorption bands of both salts are of low intensity and strongly shifted towards the short-wave part of the spectrum, but here the sulfate absorbs more strongly and at longer wavelengths than the methylperchlorate.

Like the corresponding bases, in alcohol solution the simple and quaternary salts of 2-methyl- and 1,2-dimethylbenzimidazoles have complex spectra, consisting of very narrow absorption bands. Since there is no steric hindrance here, methylation produces the usual small shift in the absorption maxima towards longer wavelengths. We present the values of the maxima of the two absorption bands of each of the salts (XIII), (XIV) and (XV).



A completely different picture is observed with 2-aryl derivatives of benzimidazole, of which we examined 2-phenyl-, 1-methyl-, 2-phenyl-, 2-p-tolyl-, 1-ethyl-2-p-tolyl-, 2-o-tolyl- and 1-ethyl-o-tolylbenzimidazoles, their sulfates and their quaternary salts. Figure 4 shows the absorption curves of the salts (XVI), (XVII) and (XVIII).

As in the case of salts of 2-arylbenzthiazoles, alkylation of the heterocycle disrupts its coplanarity with the phenyl group, noticeably lowering the extinction and shifting the absorption bands towards shorter wavelengths. Comparison of the absorption curves of the sulfate of 2-phenylbenzimidazole with the methylperchlorate of 1-methyl-2-phenylbenzimidazole shows the same regularity. Particularly great steric hindrance is observed in salts of 2-o-tolylbenzimidazole, (XIX), (XX) and (XXI), whose absorption curves are presented in Fig. 5.



Even in the molecule of salt (XX), the benzene ring is apparently turned through 90° with respect to the benzimidazole nucleus, since further alkylation has hardly any effect on the absorption curve. The absorption

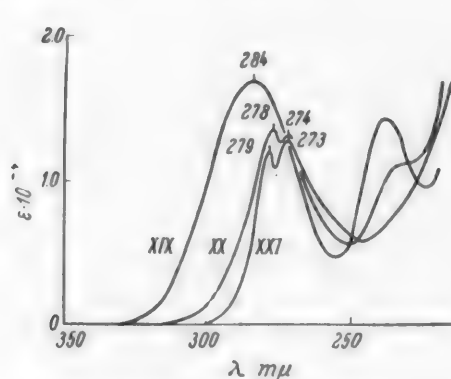


Fig. 5.

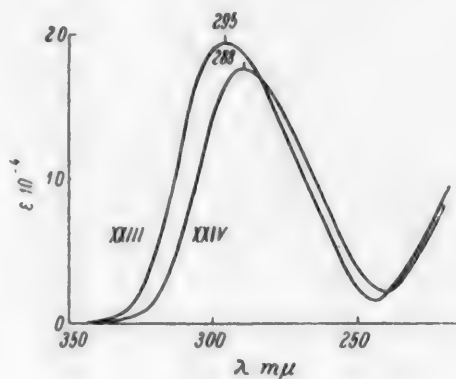
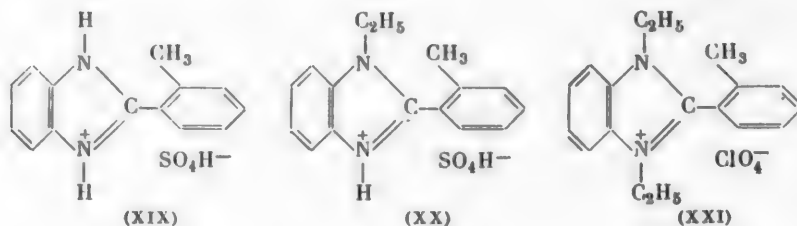


Fig. 6.

spectrum of 2-o-tolylbenzimidazole was investigated by Wiegand and Merkel [4] and also by Mangini and Montanari [5], who came to the conclusion that in this molecule steric hindrance forced the phenyl out of the plane of the molecule.



It can also be observed clearly how differently the absorption spectra change in going from the sulfates to the quaternary salts with α - and γ -phenylpyridines [19]. The formation of quaternary salts of γ -phenylpyridine does not produce steric hindrance. Therefore the methylperchlorate of γ -phenylpyridine (XXIII) absorbs more strongly and at longer wavelengths than the sulfate of γ -phenylpyridine (XXIV) (Fig. 6). The methylperchlorate of α -phenylpyridine (XXV), where the nuclei are not coplanar, on the other hand, absorbs at shorter wavelengths and less intensely than the sulfate of the same base (XXVI), as can be seen in Fig. 7. However, the absorption spectra of the sulfate (XXVII) and the methylperchlorate (XXVIII) of α -naphthoquinoline, which

can be considered as α -phenylpyridine with the phenyl group fixed in the plane of the pyridine nucleus with a vinylen bridge, as would be expected, show normal ratios of wavelengths and maximum intensities.

In our previous work [1] we did not observe essential differences in the positions of the absorption maxima of the sulfate and the ethylperchlorate of 2-p-dimethylaminophenylbenzoxazole. Hence the conclusion was that in quaternary salts of this base, due to the small radius of the oxygen in the heterocycle, the coplanarity of the nuclei was not disrupted. Now we examined the

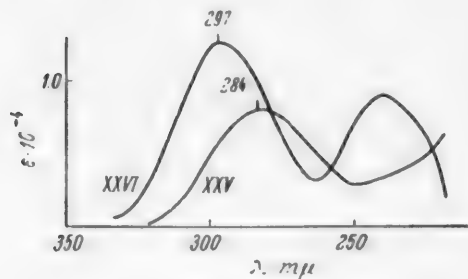
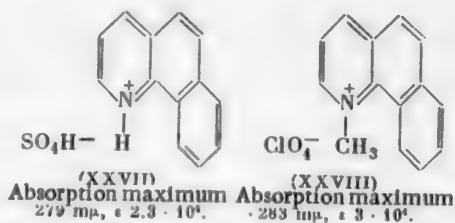
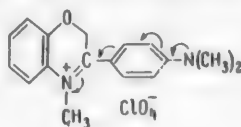


Fig. 7.



absorption curves of the sulfate and the methylperchlorate of 2-phenylbenzoxazole. Their measurement presented certain difficulties. 2-Phenylbenzoxazole is an extremely weak base. It was only possible to determine the absorption maximum of its sulfate in alcohol (300 mμ) in a solution containing 30 g of concentrated sulfuric acid per 100 ml. On the other hand, in alcohol solution the methylperchlorate of 2-phenylbenzoxazole was decomposed so rapidly that it seemed impossible to measure its absorption maximum. It was, however, noted that the addition of sulfuric acid to the alcohol inhibited the decomposition of the quaternary salt. The absorption maximum of the methylperchlorate, determined in this way, was found to be at 295 mμ, i.e. in a shorter wavelength part of the spectrum than the maximum of the sulfate. Consequently, the molecule of the quaternary salt of 2-phenylbenzoxazole, in contrast to the molecule of the quaternary salt of 2-p-dimethylaminophenylbenzoxazole, is not planar. This difference is probably due to stabilization of the coplanarity by the energy of conjugation of the dimethylamino group with the benzoxazole nucleus.



EXPERIMENTAL

2-p-Dimethylaminophenylbenzimidazole. A mixture of 2 g of o-phenylenediamine and 2.78 g of p-dimethylaminobenzaldehyde was heated for 2 hours at 180-190°. The cooled melt was powdered and extracted with boiling benzene. Cooling the benzene solution yielded 1.8 g (71%) of colorless crystals with m. p. 286-287° (with decomp.). *

Max. ** 372 (2.16), inflection ~285 (0.34), min. 250 (0.22). Base + H₂SO₄: max. 369 (2.46).

Found %: N 17.52, 17.34. C₁₅H₁₅N₃. Calculated %: N 17.72.

1-Methyl-2-p-dimethylaminophenylbenzimidazole. 0.3 g of the previous base and 0.31 g of methyl iodide were heated in benzene solution in a sealed tube at 100° for 5 hours. The hydriodide of 1-methyl-

* The melting points presented are corrected.

** The absorption maxima (max.) and absorption minima (min.) are given in millimicrons for alcohol solutions. The values of the molar extinctions, multiplied by 10⁻⁴, are given in brackets. All the spectral measurements were made on an SF-4 spectrophotometer.

2-p-dimethylaminophenylbenzimidazole was isolated as yellow needles. After recrystallization from alcohol, the substance had m. p. 226°.

Found %: I 33.66, 33.37. $C_{16}H_{15}N_3I$. Calculated %: I 33.51.

The base was liberated from the hydroiodide with alkali and had m. p. 246° (with decomp.).

Max. 330 (3.28), inflection 365 (1.10), min. 256 (0.34). Base + H_2SO_4 : max. 363 (4.40), inflection 245 (1.00), min. 283 (0.24).

Found %: N 16.46, 16.68. $C_{16}H_{17}N_3$. Calculated %: N 16.73.

The methiodide of the base was obtained by heating 1-methyl-2-p-dimethylaminophenylbenzimidazole with excess methyl iodide in acetonitrile in a sealed tube at 100° for 3 hours. The fine, colorless plates had m. p. 288-290°.

Max. 343 (2.4), min 253 (1.18).

Found %: I 32.30, 32.13. $C_{17}H_{19}N_3I$. Calculated %: I 32.29.

2-Phenylbenzthiazole was obtained from o-aminophenyl mercaptan and benzaldehyde [6] and had m. p. 114°.

Max. 297 (1.60), 225 (2.00), min. 260 (0.70) (See [7]). Base + H_2SO_4 : max. 325 (1.60), 259 (0.90), 225 (1.22), min. 270 (0.52), 243 (0.52).

The methiodide was obtained by heating the base with dimethyl sulfate and subsequent precipitation from aqueous solution with potassium iodide. The m. p. was 210° (with decomp.).

Max. 303 (1.44), 257 (0.85), inflection 246 (1.50), min. 267 (0.52), 244 (0.70).

2-p-Tolylbenzthiazole. To a solution of 1.21 g of o-aminophenyl mercaptan in 2 ml of benzene was added 1.5 g of the acid chloride of p-toluic acid in 2 ml of benzene with cooling in ice. A white precipitate formed, the benzene was evaporated and the residue washed with ammonia. The yield of base was 1.8 g (82%). After recrystallization from alcohol, the needles had m. p. 84-85° (85° [8]).

Max. 300-305 (2.00), 251 (0.75), min. 259 (0.70), 245 (0.72). Base + H_2SO_4 : max. 330 (2.04), 265 (0.90), min. 275 (0.72), 245 (0.51).

The methylperchlorate was obtained by heating the base with dimethyl sulfate and subsequent precipitation from an aqueous solution with sodium perchlorate. The needles had m. p. 184°.

Max. 310 (1.63), 263 (0.67), min. 271 (0.58), 250 (0.50).

Found %: Cl 10.52, 10.42. $C_{15}H_{14}O_4NSCl$. Calculated %: Cl 10.44.

o-Tolylbenzthiazole. 1.2 g of o-tolualdehyde mixed with 1.25 g of o-aminophenyl mercaptan was heated at 160-170° until the evolution of water ceased. The product obtained was recrystallized three times from methanol. We obtained 0.5 g (22%) of product with m. p. 59°.

Max. 283 (1.40), min. 246 (0.86). Base + H_2SO_4 : max. 305 (1.42), 262 (0.94), min 268 (0.86), 245 (0.70).

Found %: N 6.26, 6.36. $C_{14}H_{11}NS$. Calculated %: N 6.22.

The methylperchlorate was obtained as indicated above. After recrystallization from water, the needles had m. p. 206°.

Max. 292 (1.12), 240 (0.93), min 252 (0.46), 230 (0.74).

Found %: Cl 10.71, 10.92. $C_{15}H_{14}O_4NSCl$. Calculated %: Cl 10.44.

2-Methylbenzimidazole was obtained from o-phenylenediamine and acetic acid [9] and had m. p. 174°.

Max 288 (0.73), 274 (0.64), 244 (0.59), min. 277 (0.33), 258 (0.28), 275 (0.26). Base + H_2SO_4 : max. 275 (0.96), 269 (0.81), min 272 (0.33).

1,2-Dimethylbenzimidazole was obtained from the previous base by heating with methyl iodide [10]. The melting point of the trihydrate was 69° and of the anhydrous base, 112°.

Max. 282 (0.57), 275 (0.51), 251 (0.55), min 279 (0.27), 262 (0.34), 225 (0.17). Base + H₂SO₄: max. 276 (0.78), 270 (0.67), 241 (0.48), min 273 (0.32), 255 (0.32), 225 (0.26).

The methiodide was obtained by heating 2-methylbenzimidazole with excess methyl iodide in a sealed tube at 100°. After recrystallization from alcohol, the product had m. p. 265° (with decomp.) (254° [10]).

Max. 277 (0.84), 270.5 (0.77), inflection 283 (0.57), 240 (0.57), min 275 (0.40), 260 (0.51).

2-Phenylbenzimidazole was obtained from o-phenylenediamine and benzaldehyde [11] and had m. p. 292° (290° [11]).

Max. 301 (2.22), 240 (1.18), min. 255 (0.48), 233 (1.14). Base + H₂SO₄: max. 300 (2.16), 243 (1.56), min. 256 (0.38).

The methylperchlorate of 1-methyl-2-phenylbenzimidazole was obtained by heating 2-phenylbenzimidazole with excess dimethyl sulfate, treating the aqueous solution of the quaternary salt obtained with sodium perchlorate and recrystallizing the perchlorate from dilute hydrochloric acid (during recrystallization from water, cleavage of the imidazole ring occurred). The m. p. was 218-219°.

Max. 280 (1.52), min. 250 (0.46).

Found %: N 8.54, 8.82. C₁₅H₁₃O₄N₂Cl. Calculated %: N 8.68.

2-p-Tolylbenzimidazole. To a solution of 4.75 g of o-phenylenediamine and 5 g of p-tolualdehyde in 15 ml of alcohol was added a solution of 20 g of copper acetate in 250 ml of water. The mixture was heated to boiling and the precipitate sucked off and suspended in 500 ml of 50% methanol. The copper was precipitated from the boiling solution with hydrogen sulfide and the precipitate washed with hot methanol. Water was added to the filtrate until the base was precipitated completely. We obtained 4.8 g (55%) of fine plates, reminiscent of boric acid, with m. p. 271°.

Max. 320 (1.54), 305 (2.50), 244 (1.46), inflection ~295 (2.20), min 316 (1.46), 255 (0.64), 232 (1.23), Base + H₂SO₄: max. 308 (2.44), 298 (2.50), 249 (1.80), inflection ~ 323 (1.40), min. 304 (2.40), 260 (0.48), 230 (0.64).

Found %: N 13.59, 13.44. C₁₄H₁₂N₂. Calculated %: N 13.46.

1-Ethyl-2-p-tolylbenzimidazole. The action of 1 mole of diethyl sulfate on 1 mole of 2-p-tolylbenzimidazole yielded a mixture of unreacted base and the ethylethosulfate of 1-ethyl-2-p-tolylbenzimidazole. Therefore, the base we required was obtained by the general method [12]. To a solution of 1.65 g of the dihydrochloride of N-ethyl-o-phenylenediamine and 1 g of p-tolualdehyde in 30 ml of 50% alcohol was gradually added a solution of 2.68 g of copper acetate in 25 ml of water. The mixture was heated for 10 minutes at 60°. The dark, noncrystalline precipitate was washed with cold water, ground to a powder, suspended in dilute hydrochloric acid (100 ml of water + 8 ml of concentrated hydrochloric acid) and hydrogen sulfide passed through the suspension with heating. The filtrate from the copper sulfide was twice boiled with activated charcoal and the base precipitated with ammonia. The precipitate was recrystallized from petroleum ether. The yield was 0.32 g (17%) and the m. p. 105-106°.

Max. 288 (1.50), 236 (1.46), min. 251 (0.68), 239 (1.40). Base + H₂SO₄: max. 286 (1.86), 245 (1.68), min 207 (0.61), 226 (0.80).

Found %: N 11.87, 11.90. C₁₆H₁₆N₂. Calculated %: N 12.07.

The ethylperchlorate was obtained by heating 2-p-tolylbenzimidazole with 2 moles of diethyl sulfate in xylene for 10 minutes. The precipitate was dissolved in water, the unreacted base precipitated with ammonia and the quaternary salt precipitated from the filtrate was sodium perchlorate. Recrystallization from alcohol yielded rhombs with m. p. 204-205°.

Max. 280 (1.48), 240 (1.18), min. 255 (0.68), 230 (1.02).

Found %: N 9.83, 9.79. C₁₈H₂₁O₄N₂Cl. Calculated %: N 9.72.

2-o-Tolylbenzimidazole. To a solution of 9.5 g of o-phenylenediamine in 200 ml of methanol was added a solution of 10 g of o-tolualdehyde in 50 ml of methanol and then a solution of 40 g of copper acetate in 500 ml of water; 31.5 g of a light-grey copper complex precipitated on heating. Further processing was as above. We obtained 1.2 g (69%) of base, which formed thick needles with m. p. 223-224° after recrystallization from methanol.

Max. 287 (1.49), inflection ~235 (1.20), min 251 (0.63). Base + H₂SO₄: max. 284 (1.68), 240 (1.44), min. 254 (0.48), 224 (0.96).

Found %: N 13.73, 13.70. C₁₄H₁₃N₂. Calculated %: N 13.46.

The same base was described by Montanari and Passerini [13], who obtained it by another method; these authors mistakenly reported for it m. p. 111-112°.

o-Tolualdehyde, required for the synthesis of o-tolylbenzimidazole, was obtained by a very simple and convenient method, namely, oxidation of ω-chloro-o-xylene in analogy with the method of preparing p-tolualdehyde, described in the patent [14]. A mixture of 141.6 g of ω-chloro-o-xylene, obtained by chlorination of boiling o-xylene, 103.5 g of sodium bichromate and 19 g of anhydrous sodium carbonate in 535 ml of water was boiled with stirring for 4 hours. The aldehyde, which distilled with steam, was separated from water, dried with calcium chloride and fractionated in vacuum. The b. p. was 93-95° at 10 mm and the yield 70 g (52%).

1-Ethyl-2-o-tolylbenzimidazole. It was not possible to ethylate 2-o-tolylbenzimidazole with diethyl sulfate: a mixture of unreacted base and the salt of 1,3-diethyl-2-o-tolylbenzimidazole was obtained. Therefore, 1-ethyl-2-o-tolylbenzimidazole was synthesized from o-tolualdehyde and N-ethyl-o-phenylenediamine as described above for 1-ethyl-2-p-tolylbenzimidazole. The yield after recrystallization from petroleum ether was 62% and the colorless plates had m. p. 81-82°.

Max. 277 (0.97), 255 (0.83), inflection ~285 (0.86), min. 264 (0.78), 244 (0.70). Base + H₂SO₄: max. 278 (1.36), 274 (1.31), inflection ~235 (1.10), min. 275 (1.25), 250 (0.58).

Found %: N 12.26, 12.25. C₁₆H₁₆N₂. Calculated %: N 12.07.

The ethylperchlorate of the base was obtained by heating 2 g of base and 1.5 g of diethyl sulfate in 10 ml of dry benzene in a sealed tube for 1.5 hours. The oil obtained was washed with benzene and ether and dissolved in water by heating. 0.6 g of unreacted base was precipitated from the aqueous solution with ammonia. The ammoniacal filtrate was made acid with perchloric acid. The ethylperchlorate (1.1 g, 36%) precipitated and after recrystallization from alcohol it appeared as platelets with m. p. 143-144°.

Max 279.5 (1.22), 273 (1.30), min. 277 (1.08), 246 (0.58).

Found %: Cl 9.73, 9.81. C₁₈H₂₀O₄N₂Cl. Calculated %: Cl 9.74.

α- and γ-Phenylpyridines were obtained by the action of benzenediazonium chloride on pyridine [15] and purified through the picrates. α-Phenylpyridine was an oil.

Max. 277 (1.04), 245 (1.34), min 266 (0.77) (See [16]). Base + H₂SO₄: max. 297 (1.26), 242 (0.90), min. 264 (0.30).

The methylperchlorate was obtained by heating the base with dimethyl sulfate at 100° for 30 minutes and precipitation of the salt obtained from aqueous solution with sodium perchlorate; after recrystallization from alcohol, the product had m. p. 136°.

Max. 284 (0.80), min. 251 (0.28).

Found %: Cl 13.10, 13.05. C₁₃H₁₁O₄NCl. Calculated %: Cl 13.17.

γ-Phenylpyridine formed platelets with m. p. 72-73° (69-70° [15]).

Max. 261 (1.64), min. 227 (0.37). Base + H₂SO₄: max. 288 (1.74), min. 240 (0.20).

The methylperchlorate was obtained as described above; it formed platelets with m. p. 140°.

Max. 295 (1.92), min. 244 (0.15).

Found % Cl 13.25, 13.28. $C_{12}H_{12}O_4NCl$. Calculated % Cl 13.17.

2-Phenylbenzoxazole was obtained by Ladenburg's method [17] and recrystallized from aqueous alcohol. It formed needles with m. p. 103°.

Max. 299 and 291 with almost identical extinctions (See [18]). Base + H_2SO_4 : max. 300.

For preparation of the methylperchlorate, 1 g of base and 0.5 g of dimethyl sulfate were heated in 3 ml of dry benzene in a sealed tube for 8 hours at 100°. The oil which deposited crystallized after washing with dry benzene. The yield of methyl methosulfate was 1.45 g. The salt was dissolved in anhydrous alcohol and a cold saturated solution of sodium perchlorate added to the solution. The precipitated crystals of methylperchlorate were recrystallized from anhydrous alcohol. The m. p. was 222°.

Found % Cl 11.77, 11.64. $C_{14}H_{12}O_5NCl$. Calculated % Cl 11.47.

The quaternary salt rapidly decomposed, even in anhydrous alcohol, but decomposition was inhibited by the addition of concentrated sulfuric acid to the solution. The max. was at 295.

SUMMARY

The absorption maxima of the quaternary salts of 2-p-dimethylaminophenylbenzimidazole and 1-methyl-2-p-dimethylaminophenylbenzimidazole are shifted towards the shorter-wave part of the spectrum in comparison with the absorption maxima of the corresponding sulfates. This indicates the existence of steric hindrance in the molecules of the quaternary salts and disruption of the coplanarity of the nuclei. Similar observations were made with quaternary salts of a series of 2-arylbenzthiazoles and 2-arylbenzimidazoles, 2-phenylpyridine and 2-phenylbenzoxazole. Steric hindrance in these quaternary salts appears not only as a shift in the absorption maxima into the shorter-wave part of the spectrum, but also as a decrease in the intensity of absorption and as a loss of the capacity to fluoresce under an ultraviolet lamp.

LITERATURE CITED

- [1] A. L. Kiprianov and V. A. Shrubovich, *J. Gen. Chem.*, **26**, 2891 (1956).*
- [2] G. Wheland, *The Theory of Resonance*, N. Y., 161 (1945); W. Remington, *J. Am. Chem. Soc.*, **67**, 1838 (1945); P. Wittum and G. Brown, *J. Am. Chem. Soc.*, **69**, 154 (1947); W. Brown and H. Reagan, *J. Am. Chem. Soc.*, **69**, 1032 (1947).
- [3] L. Hofer, R. Grabenstetter, and E. Wiig, *J. Am. Chem. Soc.*, **72**, 203 (1950); A. L. Kiprianov and I. K. Ushenko, *Bull. Acad. Sci. USSR, Div. Chem. Sci.* 1950, 499.
- [4] Ch. Wiegand and E. Merkel, *Lieb. Ann.* **557**, 242 (1947).
- [5] A. Mangini and F. Montanari, *Bull. Sci. Fac. Chim. ind. Bologna*, **14**, 36 (1956); *Zbl.*, 1957, 12701.
- [6] M. Bogert and A. Stull, *J. Am. Chem. Soc.* **47**, 3080 (1925).
- [7] A. Cerniani and R. Passerini, *J. Chem. Soc.* 1954, 2262.
- [8] M. Bogert and M. Meyer, *J. Am. Chem. Soc.*, **44**, 1570 (1922).
- [9] *Synth. Org. Prep.*, **2**, 86 (1949).
- [10] O. Fischer, *Ber.*, **25**, 2841 (1892).
- [11] R. Weidenhagen, *Ber.* **69**, 2269 (1936).
- [12] R. Weidenhagen and G. Train, *Ber.* **75**, 1936 (1942).
- [13] F. Montanari and R. Passerini, *Bull. sci. Fac. Chim. ind. Bologna*, **11**, 42 (1953); *Ch. A.*, **48**, 6436 (1954).
- [14] German Pat. 347583; *Friedl.*, **13**, 1107.

*Original Russian pagination. See C.B. Translation.

- [15] J. Haworth, J. Hellbron, and D. Hey, *J. Chem. Soc.* 1940, 352.
- [16] A. Gillam, D. Hey, and A. Lambert, *J. Chem. Soc.*, 1941, 365.
- [17] A. Ladenburg, *Ber.*, 9, 1526 (1876).
- [18] R. Passerini, *J. Chem. Soc.*, 1954, 2257.
- [19] P. Krumholz, *J. Am. Chem. Soc.*, 73, 3489 (1951).

Received February 28, 1958

ARYLPHENAZINES

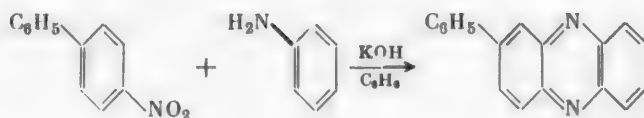
2-PHENYLPHENAZINE AND ITS DERIVATIVES

Yu. S. Rozum

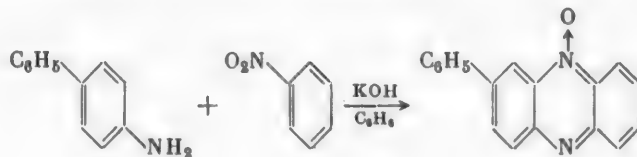
Institute of Organic Chemistry, Academy of Sciences, Ukrainian SSR

Phenazines with aryl substituents in the α - and β -positions of the ring have been unknown up to now. In the present article we describe the synthesis and properties of 2-phenylphenazine, 2-phenyl-6-methoxy- and 2-phenyl-8-methoxyphenazines, the N-oxides of these compounds, the quaternary salts of the N-monoxides and the quaternary salts of some bases of this series.

The arylphenazines were synthesized by alkaline condensation of the appropriate nitrodiphenyls with primary aromatic amines in benzene solutions. For example, 2-phenylphenazine was obtained from p-nitrodiphenyl and aniline by the scheme:



2-Phenyl-6-methoxyphenazine was obtained analogously from p-nitrodiphenyl and p-anisidine and finally, 2-phenyl-8-methoxyphenazine was obtained from p-nitrodiphenyl and o-anisidine. All the bases reacted with dilute sulfuric acid to form monoacidic salts with a red color, and with concentrated acids, diacidic salts with a green color, which were readily hydrolyzed. At 50-60°, the bases were oxidized by hydrogen peroxide in glacial acetic acid into the corresponding N-monoxides; at high temperatures (90-100°) under similar conditions, the N,N-dioxides were formed and these had a deep orange color, in contrast to the yellow monoxides. The N-monoxides of arylphenazines could also be obtained by alkaline condensation if the nitro component was added to the reaction in excess [1]. Thus, the 9-oxide of 2-phenylphenazine was obtained by alkaline condensation of p-aminodiphenyl with excess nitrobenzene.



The isomeric 10-oxide of 2-phenylphenazine was obtained by alkaline condensation of excess p-nitrodiphenyl with aniline and the 10-oxide of 2-phenyl-6-methoxyphenazine from p-anisidine with excess p-nitrodiphenyl.

The arylphenazines formed yellow needles or platelets, which were readily crystallizable from benzene or alcohol. The monoxides of 2-phenylphenazine and its derivatives appeared as yellow crystalline substances, which fluoresced strongly in chloroform or dichloroethane solutions under a quartz lamp.

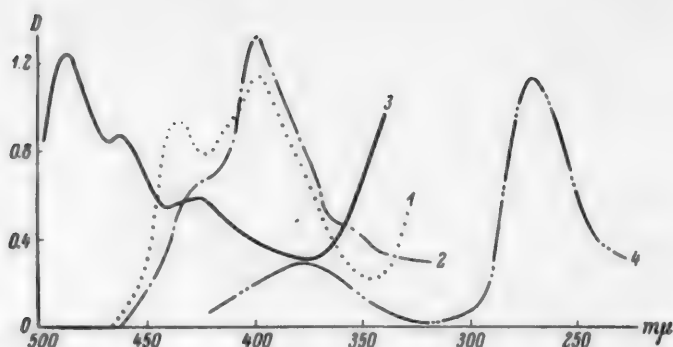


Fig. 1. Absorption spectra. 1) 9-oxide of 2-phenylphenazine, 2) 10-oxide of 2-phenylphenazine, 3) 9,10-dioxide of 2-phenylphenazine (1-3 - $c, 10^{-4} M$), 4) 2-phenylphenazine ($c, 2 \cdot 10^{-5} M$).

All the bases and their oxides described in the present work were purified by chromatography on aluminum oxide; benzene was the chromatographic developer. The bases and their oxides were characterized by the melting points, decomposition points and ultraviolet absorption spectra. As in the case of unsubstituted phenazine, the spectra of 2-phenylphenazine showed two absorption bands (Fig. 1, curve 4). The shortwave band, lying

at 270 $m\mu$, was almost 5 times as intense as the longwave band at 375 $m\mu$. Approximately the same ratios were observed for the monoxides, but with the latter, the number of bands in the longwave region was increased and the spectrum shifted towards the visible region. The spectra of the monoxides of 2-phenylphenazine had three sharp absorption bands at the same wavelengths (the shortwave bands are presented in Fig. 2). High intensity bands lay at 288 $m\mu$ and low-intensity ones at 397 and 434 $m\mu$. The band at 434 $m\mu$ for the 10-oxide of 2-phenylphenazine was diffuse. With the 9,10-dioxide of 2-phenylphenazine, bands lay at 235, 280 and 309 $m\mu$ in the shortwave region and at 428, 460, and 487 $m\mu$ in the longwave region (Figs. 1 and 2, curve 3). The monoacidic salt of 2-phenylphenazine had an absorption maximum at 464 $m\mu$; the diacidic salt absorbed at 620 $m\mu$.

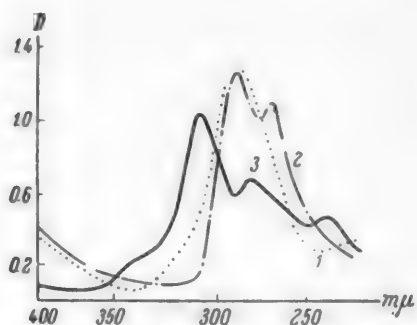
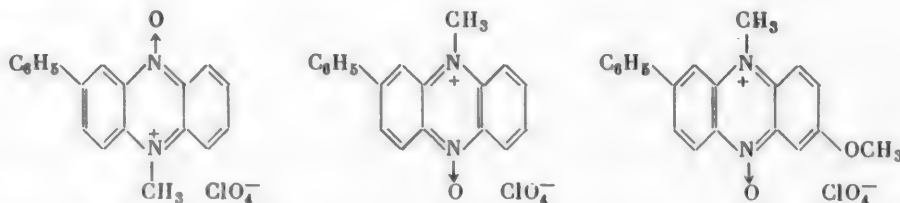


Fig. 2. Absorption spectra ($c = 2.5 \cdot 10^{-5} M$). 1) 9-oxide of 2-phenylphenazine, 2) 10-oxide of 2-phenylphenazine, 3) 9,10-dioxide of 2-phenylphenazine.

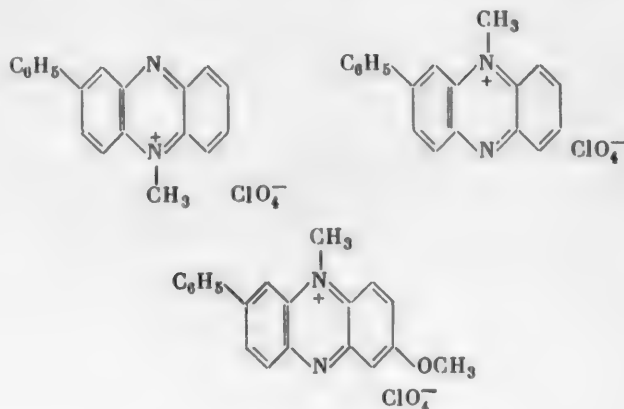
We showed previously [2] that when heated in nitrobenzene with dimethyl sulfate, the N-monoxides of phenazine and quinoxaline added the alkyl ion not to the oxygen, as occurs with N-oxides of pyridine and quinoline in reactions with methyl iodide

[3], but to the second nitrogen atom of the heterocycle. This gave compounds of a new type, quaternary salts of N-monoxides of phenazine, quinoxaline and their various derivatives. Using this reaction to obtain the quaternary salts of the N-monoxides of 2-phenylphenazine, we obtained two isomeric quaternary salts of the 9- and 10-oxides of 2-phenylphenazine and one quaternary salt of the 10-oxide of 2-phenyl-6-methoxyphenazine.



Quaternary salts of N-monoxides of 2-phenylphenazine and 2-phenyl-6-methoxyphenazine crystallized as red needles, melted with decomposition above 200°, dissolved readily in water and alcohol and reduced with

zinc dust in the cold to the corresponding quaternary salt bases. By this method we obtained the corresponding quaternary salts of the bases from the salts listed:



Direct alkylation of 2-phenylphenazine with dimethyl sulfate gave a 92% yield of a quaternary salt which did not depress the melting point of the 2-phenyl-10-methylphenazinium salt (m. p. 204-205°); the spectra of these salts agreed completely. Thus, the phenyl group in position 2 directs the alkyl ion to the nitrogen at position 10 during the formation of a quaternary salt. This is not difficult to explain from the properties of the C_6H_5 group as an electrophilic substituent in the phenazinerings; apparently, the phenyl group attracts the unshared pair of electrons from the nitrogen atom at 9, with which it is in conjugation, and the alkyl ion adds to the nitrogen atom at 10, which has a higher electron density. This tendency is even more clearly expressed by 2-phenyl-6-methoxyphenazine, in which, due to the combined action of the C_6H_5 - and OCH_3 - groups, the electron density at nitrogen atom 10 is higher than in 2-phenylphenazine.

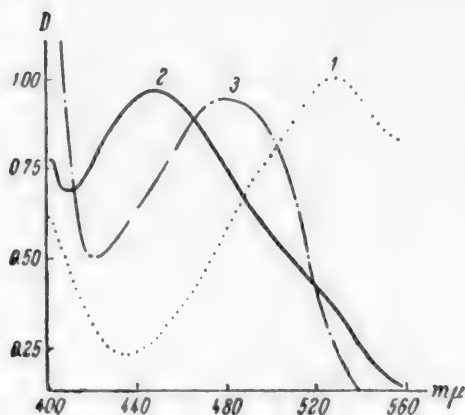
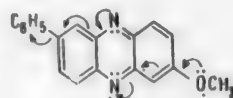
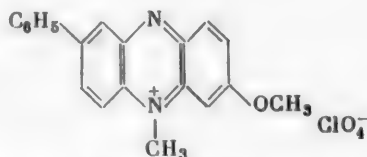


Fig. 3. Absorption spectra. Explanation in text.

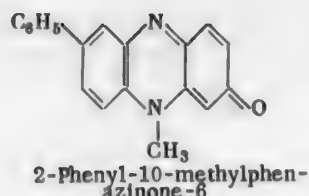
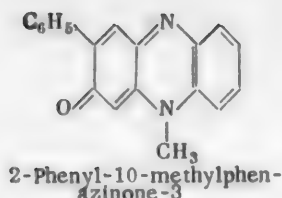


Therefore, the action of dimethyl sulfate on 2-phenyl-6-methoxyphenazine gives a quantitative yield of a quaternary salt with the following structure.

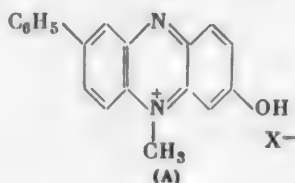


The structures of the quaternary salts of 2-phenyl-9-methylphenazine and 2-phenyl-6-methoxy-9-methylphenazine are anomalous and under natural conditions during direct alkylation of the base, apparently are formed on insignificant amounts or are not formed at all. Even with the careful indirect method of obtaining them for the quaternary salts of the N-oxides, the 2-phenyl-9-methylphenazinium salt was formed in 30% yield and the 2-phenyl-6-methoxy-9-methylphenazinium salt in only 8% yield.

Quaternary salts of 2-phenylphenazine bases were readily oxidized with potassium ferricyanide in alkaline solution with the formation of red phenazinones. The quaternary 2-phenyl-10-methylphenazinium salt we oxidized gave one of two possible phenazinones.



The problem of which of these structures corresponded to the 2-phenyl-10-methylphenazinone we obtained was solved by an investigation of the absorption spectrum of the phenazinone obtained in acidified alcohol and the spectrum of the quaternary 2-phenyl-6-methoxy-10-methylphenazinium salt in neutral solution. The molecule of 2-phenyl-10-methylphenazinone-6, adding a molecule of acid, is converted into a quaternary salt of structure (A), whose spectrum is similar to that of the quaternary 2-phenyl-6-methoxy-10-methylphenazinium salt. Figure 3 shows three absorption curves; curve 1 belongs to the phenazinone in alcohol solution, curve 2



to the phenazinone in acid and curve 3 to the quaternary 2-phenyl-6-methoxy-10-methylphenazinium salt. Had our phenazinone had the structure of 2-phenyl-10-methylphenazinone-6, curves 2 and 3 would have been similar. In the case considered, they differed strongly. Consequently, the phenazinone we obtained had the structure of 2-phenyl-10-methylphenazinone-3.

EXPERIMENTAL

2-Phenylphenazine. 80 g of p-nitrodiphenyl, 47 g of aniline and 120 g of powdered KOH were boiled in 500 ml of benzene with stirring for 27 hours. The benzene solution was decanted and the solid precipitate washed free from alkali with water and then extracted with hot benzene. The benzene extracts were combined and steam distilled. The distillation residue was chromatographed in benzene on aluminum oxide. The bottom zone yielded 9.2 g of p-phenylazobenzene; the orange plates had m. p. 153° (151° [4]). The next zone (pale yellow) yielded 9.4 g (9.1%) of 2-phenylphenazine; the light-yellow needles had m. p. 147°. The product was readily soluble in benzene, toluene and dichloroethane; it dissolved with difficulty in ligroin and was insoluble in water. It crystallized from alcohol. With concentrated sulfuric acid, the substance formed a green diacidic salt, which was converted into a red monosalt by partial hydrolysis; it was precipitated from solution as fine yellow needles by complete hydrolysis.

Found %: N 10.86, 10.68. $C_{18}H_{12}N_2$. Calculated %: N 10.93.

2-Phenyl-6-methoxyphenazine was obtained similarly from 40 g of p-nitrodiphenyl, 40 g of p-anisidine and 100 g of KOH, which were boiled in benzene (600 ml) for 27 hours. The yield was 11.9 g (21%). The yellow platelets had m. p. 156°. As regards behavior towards acids and solvents, the product was similar to the one above. It crystallized from alcohol. The base was found in the second zone of the chromatogram.

Found %: N 9.82, 9.71. $C_{19}H_{14}ON_2$. Calculated %: N 9.79.

2-Phenyl-8-methoxyphenazine. 40 g of p-nitrodiphenyl, 40 g of o-anisidine, 100 g of KOH and 600 ml of benzene were boiled for 24 hours. The second zone of the chromatogram yielded 2.5 g of an orange oil (not investigated). The third zone (yellow) yielded 0.6 g (1%) of 2-phenyl-8-methoxyphenazine. The light-yellow needles had m. p. 159°. The dark-yellow fourth zone yielded 8.9 g (17.4%) of 2-phenylphenazine, formed as a result of elimination of the methoxy group. 2-Phenyl-8-methoxyphenazine dissolved in sulfuric acid with the formation of a green diacidic salt.

Found %: N 9.67, 9.82. $C_{19}H_{14}ON_2$. Calculated %: N 9.79.

9-Oxide of 2-phenylphenazine. 42 g of p-aminodiphenyl, 45 g of nitrobenzene, 60 g of KOH and 250 ml of benzene were boiled for 17 hours. The reaction product was treated as above. The residue after steam distillation was dissolved in a mixture of benzene and dichloroethane (1 : 1) and mixed with 20% hydrochloric acid (200 ml). The red salt precipitated was separated and treated with aqueous ammonia. The base was dried and put onto a chromatography column as a benzene solution. The fourth zone from the bottom yielded 11 g (16%) of the 9-oxide of 2-phenylphenazine. The yellow needles had m. p. 135° (from o-xylene) and decomp. p. 199-201°.

Found %: N 10.38, 10.18. $C_{18}H_{12}ON_2$. Calculated %: N 10.29.

10-Oxide of 2-phenylphenazine was obtained in the synthesis of 2-phenylphenazine. It was isolated from the third zone of the chromatogram (0.8 g, 0.7%). The clear yellow plates had m. p. 168° and decomp. p. 200-203°. It gave off a green fluorescence in chloroform solution under a quartz lamp.

Found %: N 10.25, 10.29. $C_{18}H_{12}ON_2$. Calculated %: N 10.29.

10-oxide of 2-phenyl-6-methoxyphenazine. 139 g of p-nitrodiphenyl, 62 g of p-anisidine, 120 g of KOH and 500 ml of benzene were boiled for 25 hours. The reaction product was treated as above. The second zone of the chromatogram yielded 8.5 g (6%) of 2-phenyl-6-methoxyphenazine and the third zone 16 g (10.5%) of the 10-oxide of 2-phenyl-6-methoxyphenazine. The yellow (yellow orange under a quartz lamp) needles had m. p. 188° and decomp. p. 210-211°; in chloroform and dichloroethane solutions under a quartz lamp, the product fluoresced with a yellow-green light. It was readily oxidized into the N,N-dioxide with hydrogen peroxide.

Found %: N 9.36, 9.40. $C_{19}H_{14}O_2N_2$. Calculated %: N 9.27.

9,10-Dioxide of 2-phenylphenazine. To a solution of 1.5 g of 2-phenylphenazine in 25 ml of glacial acetic acid at 80-90° was added 20 ml of 20% hydrogen peroxide dropwise over a period of 6 hours. After 20 hours, the precipitate was collected and washed with water, alcohol and ether. The yield was 0.7 g (41%). Chromatography in benzene on an aluminum oxide column gave lustrous red crystals with m. p. 166° and decomp. p. 171°. The crystals became strongly electrified on grinding.

Found %: N 9.75, 9.66. $C_{18}H_{12}O_2N_2$. Calculated %: N 9.72.

The 9,10-dioxide of 2-phenyl-6-methoxyphenazine was obtained similarly from 1.5 g of 2-phenyl-6-methoxyphenazine at 80-90° in 50 ml of glacial acetic acid. The cooled solution was poured into 250 ml of water and the product extracted with chloroform and then chromatographed on aluminum oxide from the minimal amount of $CHCl_3$ and developed with benzene. The yield was 0.35 g (21%). The red needles had m. p. 181° (from benzene).

Found %: N 9.10, 9.27. $C_{19}H_{14}O_2N_2$. Calculated %: N 8.80.

9-Oxide of 2-phenyl-10-methylphenazinium perchlorate (and methyl sulfate). To a solution of 1.4 g of the 9-oxide of 2-phenylphenazine in 2 ml of nitrobenzene at 110-115° was added 1.3 ml of dimethyl sulfate and heating continued at 120-125° for 10 minutes. At this temperature, crystallization of the quaternary salt began. The nitrobenzene and dimethyl sulfate were washed out on a filter with o-xylene and ether. The yield was 1.7 g (85%). The bright-red needles had m. p. 179° (decomp.). The perchlorate had m. p. 224° (decomp.). The product was purified by recrystallization from 50% alcohol.

Found %: N 7.22, 7.20. $C_{19}H_{15}O_5N_2Cl$. Calculated %: N 7.24.

The 10-oxide of 2-phenyl-10-methylphenazinium perchlorate was obtained similarly from 1.3 g of the 10-oxide of 2-phenylphenazine in a yield of 0.9 g (48%). The red needles had m. p. 216° (decomp.). The product was recrystallized from alcohol.

Found %: N 7.30, 7.24. $C_{19}H_{15}O_5N_2Cl$. Calculated %: N 7.24.

The 10-oxide of 2-phenyl-6-methoxy-9-methylphenazinium perchlorate was obtained similarly from 1 g of the 10-oxide of 2-phenyl-6-methoxyphenazine in quantitative yield. The product formed red needles (from 50% alcohol). The m. p. was 242° (decomp.).

Found %: N 6.72, 6.72; Cl 8.58, 8.70. $C_{20}H_{17}O_6N_2Cl$. Calculated %: N 6.72; Cl 8.52.

2-Phenyl-10-methylphenazinium perchlorate. To a solution of 0.5 g of the 9-oxide of 2-phenyl-10-methylphenazinium methylsulfate in 5 ml of water at 15-20° was added (with stirring) 0.5 g of zinc dust. The reduction was exothermic and the temperature rose to 37° and the reaction was complete in 10-12 minutes. The orange solution thus became dark yellow. It was filtered free from zinc dust and the quaternary salt precipitated with sodium perchlorate. The yield was 0.4 g (87%). The product was recrystallized twice from 50% alcohol. The yellow needles had m. p. 204-205° (decomp.).

Found %: N 7.44, 7.59; Cl 10.02, 10.15. $C_{19}H_{15}O_4N_2Cl$. Calculated %: N 7.56; Cl 9.58.

2-Phenyl-9-methylphenazinium perchlorate was obtained similarly from 0.5 g of the 10-oxide of 2-phenyl-9-methylphenazinium methylsulfate in 30% yield. The yellow needles had m. p. 237° (decomp.).

Found %: N 7.50, 7.59; Cl 9.71, 9.53. $C_{19}H_{15}O_4N_2Cl$. Calculated %: N 7.56; Cl 9.58.

2-Phenyl-6-methoxy-9-methylphenazinium perchlorate was obtained similarly from 0.3 g of the 10-oxide of 2-phenyl-6-methoxy-9-methylphenazinium methylsulfate in 8% yield. The brown needles had m. p. 165-167°.

Found %: Cl 8.73, 8.72. $C_{20}H_{17}O_5N_2Cl$. Calculated %: Cl 8.86.

2-Phenyl-N-methylphenazinium perchlorate. 2.56 g of 2-phenylphenazine in 3 ml of nitrobenzene was heated at 110-115° until the base dissolved completely, 3 ml of dimethyl sulfate added and heating continued for 10 minutes at the same temperature. The nitrobenzene and dimethyl sulfate were washed out with o-xylene and ether. The yield was 3.5 g (92%). The perchlorate formed brown platelets with m. p. 204-205° (decomp.). A mixed-melting point with the preparation obtained by reduction of the 9-oxide of 2-phenyl-10-methylphenazinium methylsulfate was not depressed.

Found %: N 7.44, 7.59; Cl 10.02, 10.15. $C_{19}H_{15}O_4N_2Cl$. Calculated %: N 7.56; Cl 9.58.

2-Phenyl-6-methoxy-10-methylphenazinium perchlorate was obtained similarly from 0.5 g of 2-phenyl-6-methoxyphenazine in 1 ml of nitrobenzene with 0.5 ml of dimethyl sulfate at 100-115° in quantitative yield. The reddish brown needles had m. p. 177° (decomp.). The perchlorate had m. p. 236-237° (decomp.).

Found %: N 7.02, 6.91. $C_{20}H_{17}O_5N_2Cl$. Calculated %: N 6.99.

2-Phenyl-10-methylphenazinone-3. To a solution of 3.6 g of 2-phenyl-10-methylphenazinium methylsulfate in 60 ml of water was added 8 g of potassium ferricyanide in 40 ml of water and then 20 ml of 10% NaOH dropwise over a period of half an hour. The red phenazinone precipitated as an oil was extracted with chloroform and chromatographed on a column with aluminum oxide. The m. p. was 142°. The phenazinone dissolved in alcohol, chloroform and benzene; it was difficultly soluble in water. The absorption maximum in alcohol lay at 530 mμ. The product formed red needles from benzene. The yield was 0.4 g (15%).

Found %: N 9.76, 9.67. $C_{19}H_{14}ON_2$. Calculated %: N 9.79.

The absorption spectra were measured on SF-4 and SF2M apparatuses. A. A. Kisilenko participated in the work.

SUMMARY

We synthesized 2-phenyl-, 2-phenyl-6-methoxy- and 2-phenyl-8-methoxyphenazines, their mono- and dioxides (the 9-oxide and 10-oxide of 2-phenylphenazine, the 10-oxide of 2-phenyl-6-methoxyphenazine and the 9,10-dioxides of 2-phenyl- and 2-phenyl-6-methoxyphenazines), quaternary salts of the monoxides and quaternary salts of the bases. The UV absorption spectra of 2-phenylphenazine and its monoxides and N,N-dioxides were studied. A phenazinone was obtained from the quaternary salt of 2-phenylphenazine and its structure determined.

LITERATURE CITED

- [1] Z. V. Pushkareva and G. I. Agibalova, J. Gen. Chem., 8, 151 (1938).
- [2] Yu. S. Rosum and N. N. Lisovskaya, J. Gen. Chem. 29, 228 (1959).*

[3] M. Henze, Ber. 70, 1270 (1937); A. Katritzky, J. Chem. Soc., 1956, 2404; W. Feely, W. Leta, and V. Boekelheide, J. Org.Chem. 22, 1135 (1957); Y. Gardner and A. Katritzky, J. Chem. Soc. 1957, 4375.

[4] E. Bandrowski and A. Prokopeczko, Zbl., 1904, I, 1491.

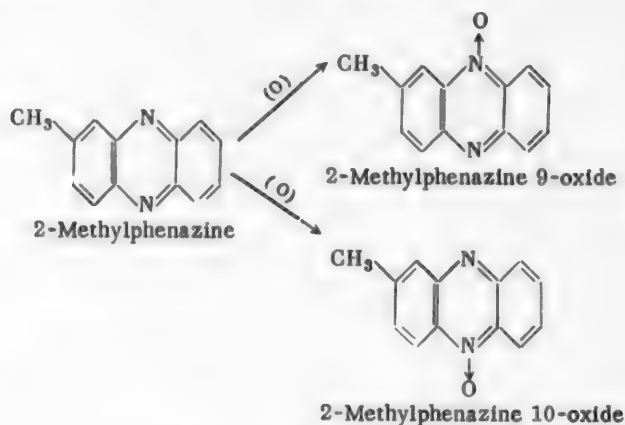
Received March 13, 1958

THE DIRECTING ACTION OF SUBSTITUENTS IN THE FORMATION OF PHENAZINE N-OXIDES

Yu. S. Rozum and A. L. Kiprianov

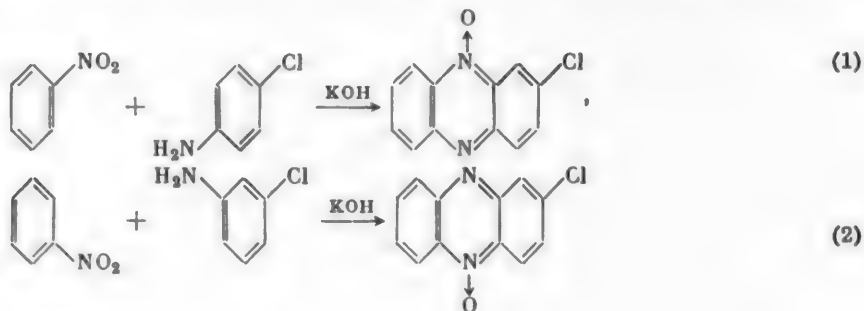
Institute of Organic Chemistry, Academy of Sciences, Ukrainian SSR

In the reaction of oxidants with monosubstituted phenazine derivatives, the formation of two isomeric monoxides is possible.



In the oxidation, the oxygen atom is an electron acceptor. Therefore attack by the oxidizing agent must be directed predominantly towards that nitrogen atom of the unsymmetrically substituted phenazine molecule that has the greatest electron density.

In the present work we investigated the directing action of the following substituents: a 2-methoxy group, a chlorine atom in position 2 and a chlorine atom in position 1. The ratio of the monoxides formed was determined from the ultraviolet absorption spectra. The method consisted of the following. For each of the cases investigated, the two expected monoxides were prepared separately beforehand. This was done by alkaline



condensation of the appropriate aromatic amines with nitro compounds. As is known, the oxygen atom in such condensations arises due to the nitro group [1]. Therefore, two isomeric oxides, for example of 2-chlorophenazine, were obtained as a result of the preceding condensations.

The absorption curves of the two N-oxide isomers were determined in benzene or alcohol solutions of known concentration on an SF-4 spectrophotometer. Then a mixture of the same monoxides was obtained by

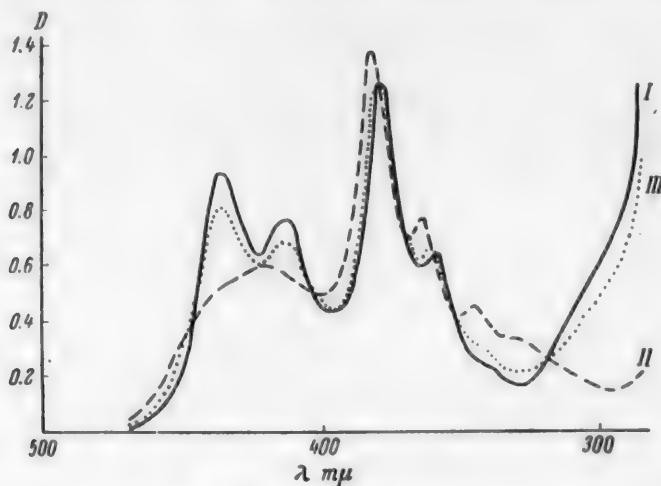


Fig. 1. Explanation in text.

oxidation of a sample of the appropriate phenazine derivative in glacial acetic acid with hydrogen peroxide. The reaction product was chromatographed to completely separate the mixture of the two N-oxides from unreacted base (the base appeared below the mixture of monoxides on the column) and N,N-dioxide (above the mixture of monoxides on the column). A sample of the mixture of isomeric monoxides was dissolved in benzene or alcohol and the absorption curve of the mixture determined. From the absorption curve of the binary mixture and the absorption curves of the two individual components, it was not difficult to calculate the content of each component in the mixture [2].

The method was first checked on artificial mixtures and shown to be sufficiently accurate for our purposes. In an artificial mixture of the two monoxides of 1-chlorophenazine in a ratio of 1 : 1, from the absorption curves we found 51.7% of one isomer and 48.3% of the second. With an artificial mixture of the monoxides

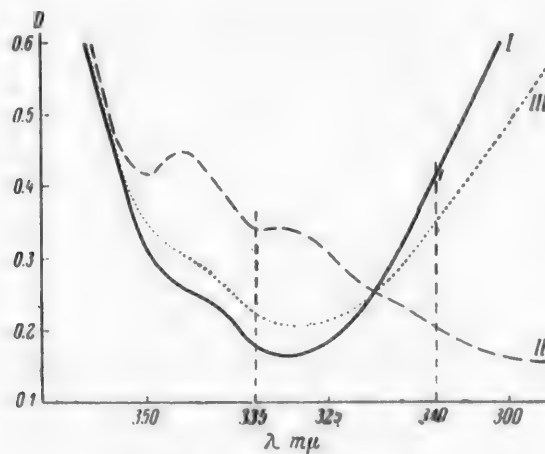


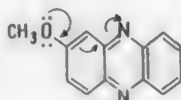
Fig. 2. Explanation in text.

of 2-chlorophenazine in a ratio of 2 : 1, the absorption curves showed a 65.9% content of one isomer and a 34.1% content of the second. In other experiments of this series, with the correct choice of the sections of the absorption curves, the errors were not greater than 2%.

Figure 1 shows the absorption curves of alcohol solutions (concentrations of 10^{-4} M, 2.26 mg per 100 ml) of the 9-oxide of 2-methoxyphenazine (I), the 10-oxide of 2-methoxyphenazine (II) and a mixture of them (III), obtained by oxidation of 2-methoxyphenazine with hydrogen peroxide in glacial acetic acid.

For the calculations we used the extinction values at the wavelengths of 310 and 335 $m\mu$. This section of the spectral curves, which was most convenient for the calculations, is shown on a large scale in Figure 2.

Calculation showed that there was 70.8% of the 9-oxide of 2-methoxyphenazine in the mixture and 29.2% of the 10-oxide of 2-methoxyphenazine. Thus, in the oxidation of 2-methoxyphenazine with hydrogen peroxide, the 9-oxide was formed predominantly. This was to be expected in view of the fact that the methoxy group raises the electron density at the nitrogen atom at position 9, with which it is conjugated.



As in the previous case, Fig. 3 shows the chosen section of the absorption curves of benzene solutions (concentration $4 \cdot 10^{-4}$ M, 9.22 mg per 100 ml) of the 9-oxide of 2-chlorophenazine (I), the 10-oxide of 2-chlorophenazine (II) and a mixture of them (III) obtained by oxidation of 2-chlorophenazine with hydrogen peroxide.

Calculation from the extinctions at the wavelengths of 310 and 335 $m\mu$ gave a 9-oxide content of 52.9% and a 10-oxide content of 47.1%. Calculations from the extinctions at 306 and 330 $m\mu$ gave 53.2% of 9-oxide and 46.8% of 10-oxide. Thus, in this case the difference in the rates of formation of the two isomeric N-oxides of 2-chlorophenazine was small and almost within the limits of experimental error. If we accept the slight predominance of the 9-oxide in the mixture, which we found, it is not difficult to explain this in terms of the

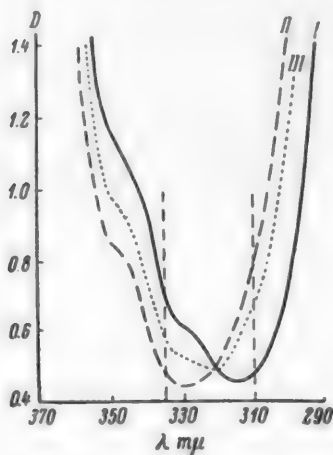


Fig. 3. Explanation in text.

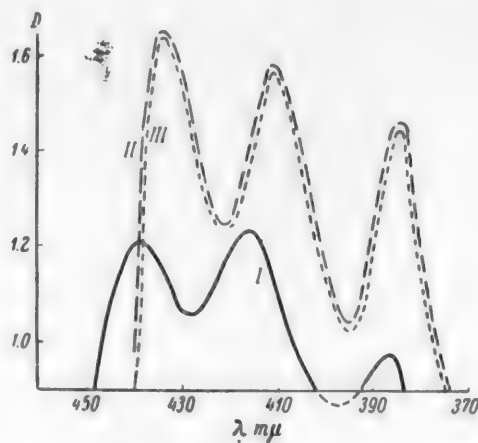


Fig. 4. Explanation in text.

properties of the chlorine atom as a substituent in an aromatic nucleus. Due to its inductive effect, it attracts electrons from both nitrogen atoms (the oxidation of 2-chlorophenazine proceeded much more slowly than the oxidation of unsubstituted phenazine); however, electrons are drawn away less from the nitrogen atom in position 9, with which the chlorine atom is in conjugation.

The absorption curves of the 9-oxide of 1-chlorophenazine (I) and the 10-oxide of 1-chlorophenazine (II) in benzene solution (concentration $2 \cdot 10^{-4}$ M, 4.61 mg per 100 ml) are presented in Fig. 4. As the figure

shows, the absorption curve (at the same concentration) of the oxidation product of 1-chlorophenazine with hydrogen peroxide (III) coincides completely with the absorption curve of the 10-oxide of 1-chlorophenazine. Consequently, in this case the oxidation formed only the 10-oxide. Its formation was due to the conjugation of the chlorine atom with the nitrogen atom in position 10 and steric hindrance to the entry of an oxygen atom to position 9, adjacent to the chlorine atom. The latter factor is apparently the main one.

EXPERIMENTAL

9-Oxide of 2-methoxyphenazine. 74 g of p-anisidine, 100 g of nitrobenzene and 150 g of KOH powder were boiled in 1 liter of benzene for 18 hours. The reaction mixture was poured into water and the oily layer separated from the aqueous one. The benzene and volatile substances were removed by steam distillation and the residue extracted with 20% hydrochloric acid. The hydrochloric acid solution of the N-oxide was filtered and the N-oxide precipitated with alkali, dissolved in benzene and chromatographed on aluminum oxide. After development of the chromatogram with benzene, the second zone from the bottom yielded 6.3 g (6%) of the 9-oxide of 2-methoxyphenazine. The yellow crystals had m. p. 179° (179° [3]).

The 9-oxide of 2-chlorophenazine was obtained as above from 25 g of p-chloroaniline, 50 g of nitrobenzene, 80 g of KOH and 500 ml of benzene by boiling for 10 hours. The yield was 8.7 g (19%). The yellow needles had m. p. 178° (175-176° [4]).

The 10-oxide of 2-chlorophenazine was obtained analogously from 37 g of aniline, 63 g of p-nitrochlorobenzene, 100 g of KOH and 500 ml of benzene by boiling for 19 hours. The yield was 11.2 g (12%). The yellow needles had m. p. 178° (178° [4]). A mixed-melting point of the 9-oxide and the 10-oxide was 150°.

The 10-oxide of 2-methoxyphenazine with m. p. 176-177° [3], the 9-oxide of 1-chlorophenazine with m. p. 143° [5] and the 10-oxide of 1-chlorophenazine with m. p. 159-160° [5] were presented to us by S. B. Serebryanyi.

Oxidation of 2-methoxyphenazine. Over a period of 9 hours, 20 ml 20% hydrogen peroxide was added dropwise to 1 g of 2-methoxyphenazine in 50 ml of glacial acetic acid at 50-60°. The reaction liquid was diluted with 500 ml of water and left to crystallize at 18-20° for 12 hours. The voluminous crystalline precipitate was collected, washed with water and dried in a desiccator. The filtrate was extracted with chloroform and removal of the solvent from the extract yielded a small amount of the N-oxide which was added to the bulk of the product obtained. The yield of the mixture of products was 0.9 g. The mixture was resolved chromatographically on aluminum oxide. The first zone, counting from the bottom, contained unoxidized 2-methoxyphenazine and the second zone contained a mixture of N-monoxides (clear yellow fluorescence under a quartz lamp with an ultraviolet filter). From the second zone we isolated 0.470 g of monoxides. The orange upper zone yielded 0.400 g of the 9,10-dioxide of 2-methoxyphenazine.

Oxidation of 2-chlorophenazine. 0.5 g of 2-chlorophenazine in 25 ml of acetic acid was oxidized as above at 60-80° with 10 ml of hydrogen peroxide. The yield was 0.52 g. After chromatography, we isolated traces of unoxidized base from the first zone, a mixture of N-monoxides of 2-chlorophenazine (0.274 g) from the second and 0.23 g of the 9,10-dioxide of 2-chlorophenazine from the third.

Oxidation of 1-chlorophenazine. As in the previous case, 0.3 g of 1-chlorophenazine was oxidized at 60-80° with 6 ml of hydrogen peroxide. The yield was 0.31 g. Two zones appeared on the chromatogram; the lower one yielded 0.21 g of the N-monoxide of 1-chlorophenazine and the upper one, 0.05 g of the 9,10-dioxide of 1-chlorophenazine.

Analysis of the mixture of N-oxides. On an SF-4 spectrophotometer we determined the absorption curves of the 9- and the 10-oxides of 1-chlorophenazine, each in benzene solution (concentration $2 \cdot 10^{-4}$ M, 4.61 mg per 100 ml of benzene), and also the absorption curve of a mixture of the two oxides, prepared by dissolving 2.30 mg of the 9-oxide and 2.30 mg of the 10-oxide in 100 ml of benzene.

Let us designate the percentage content of the 9-oxide in the artificial mixture by x and that of the 10-oxide by y . Then, assuming that the concentrations of the individual oxides in the solutions used for determining their absorption curves, and also the total concentration in the mixture of the two oxides are equal, we can calculate x and y from the formulas:

• The formulas are the solution of a system of two equations:

$$100 \cdot A_x = A_{xz}x + A_{yz}y; 100 \cdot A_y = A_{xy}x + A_{yy}y.$$

$$x = \frac{100 \cdot (A_x A_{yy} - A_{yx} A_y)}{A_{xx} A_{yy} - A_{xy} A_{yx}} \quad y = \frac{100 \cdot (A_y A_{xx} - A_{xy} A_x)}{A_{xx} A_{yy} - A_{xy} A_{yx}}$$

The letters A with indexes denote the absorption densities at the two chosen wavelengths, λ_1 and λ_2 ; absorption densities at λ_1 : A_x - mixture of oxides, A_{xx} - 9-oxide and A_{yx} - 10-oxide; absorption densities at λ_2 : A_y - mixture of oxides, A_{xy} - 9-oxide and A_{yy} - 10-oxide (Fig. 5).

In our case, measurement of the absorption densities at 360 m μ gave the values: A_x 0.552, A_{xx} 0.505, A_{yx} 0.612; at 310 m μ : A_y 0.375, A_{xy} 0.462, A_{yy} 0.305. Introducing these values into the formulas given above, we obtained the values $x = 47.6\%$ and $y = 51.0\%$. As a result of the inaccuracy of the measurement, the total of x and y deviates from 100%. Adjusting it to 100%, we finally obtain $x = 48.3\%$ and $y = 51.7\%$.

The percentage contents of the 9- and 10-oxides of 2-chlorophenazine were determined similarly in benzene solutions of an artificial mixture, where these oxides were in a weight ratio of 2 : 1.

For a mixture of N-monoxides of unknown composition, obtained by oxidation of 2-chlorophenazine, for the wavelengths 310 and 335 m μ , we found $x = 52.9\%$ and $y = 47.1\%$ and for 306 and 330 m μ , $x = 53.2\%$ and $y = 46.8\%$.

Standard samples of the monoxides of 2-methoxyphenazine were measured at a concentration of 10^{-4} M (2.26 mg in 100 ml of alcohol). A mixture of 9- and 10-oxides of 2-methoxyphenazine, obtained by oxidation of 2-methoxyphenazine, was measured at the same concentration. For the measurement, the points at 310 and

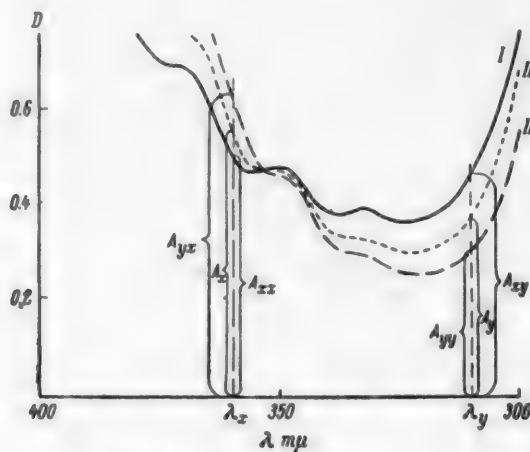


Fig. 5. Explanation in text.

335 m μ were chosen. We found 70.8% of 9-oxide of 2-methoxyphenazine and 29.2% of 10-oxide of 2-methoxyphenazine; at 382 and 436 m μ , we obtained the value 71.5% for the 9-oxide of 2-methoxyphenazine and 28.4% for the 10-oxide.

A. A. Kisilenko participated in the spectrophotometric measurements.

SUMMARY

By means of a spectrophotometric method, determinations were made of the percentage content of the isomeric N-oxides, formed during the oxidation of 2-methoxy-, 2-chloro- and 1-chlorophenazines with hydrogen peroxide in acetic acid.

LITERATURE CITED

- [1] Z. V. Pushkareva and G. I. Agibalova, J. Gen. Chem. 8, 151 (1938).

[2] E. Sterns, Absorption Spectroscopy. Coll. Foreign Lit. Press, 289 (1953);* R. Friedel and M. Orchin. Ultraviolet spectra of aromatic compounds. N. Y. (1951).

[3] S. B. Serebryanyi, Ukr. Chem. J., 21, 356 (1955); I. Ioshioke and H. Otomaru, Pharm. Bull. Japan; I, 66 (1953); Ch. A. 49, 12492e (1955).

[4] Irw. Pachter and M. Kloetzel, J. Am. Chem. Soc. 74, 972 (1952); V. P. Chernetskii and S. B. Serebryanyi, J. Gen. Chem., Coll. I, 646 (1953).

[5] S. B. Serebryanyi, Ukr. Chem. J., 21, 350 (1955).

Received February 7, 1958

* Russian translation.

CYANINE DYES CONTAINING FLUORINE

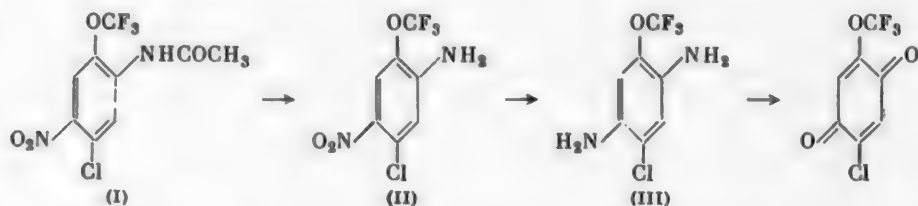
VL SYNTHESIS OF CYANINE DYES FROM 5-TRIFLUOROMETHOXY-6-ACETYLAMINOBENZTHIAZOLE

L. M. Yagupol'skii

Institute of Organic Chemistry, Academy of Sciences Ukrainian SSR

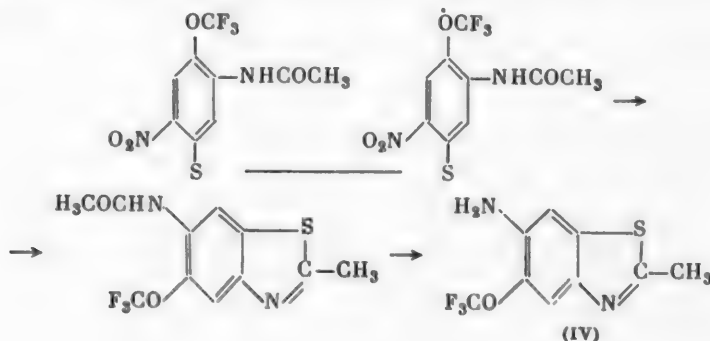
In a previous communication [1], a synthesis was described for thiacyanines containing trifluoromethoxy groups as substituents in the 5 and 6 positions of the benzthiazole nucleus. It is known that the introduction of methoxy groups into the 5,5'-positions of 6,6'-disubstituted thiacyanines (apart from 6,6'-bis-dialkylamino derivatives in which there is steric hindrance to the substituents taking up a planar disposition) produces an additive shift in the absorption maximum of the dyes towards the long-wave part of the spectrum [2]. It was interesting to determine the nature of the effect of trifluoromethoxy groups introduced into the 5,5'-positions on the absorption maxima of 6,6'-disubstituted thiacyanines.

The starting material used for the preparation of these dyes was 2-acetylamin-4-chloro-5-nitrophenyl trifluoromethyl ether (I), which was isolated from a mixture of appropriate nitroacetyl amino derivatives [1]. For proof of the structure of (I), after it had reached a constant melting point, it was deacetylated and reduced to a diamine. The latter, like other para-diamines gave an intense indamine reaction on treatment with ferric chloride. Like the corresponding methoxy derivative [3], it was readily oxidized to a p-quinone.



The quinone obtained was a yellow crystalline substance with a pleasant cinnamon smell.

(I) was converted into 6-amino-5-trifluoromethoxybenzthiazole (IV) by the method described in the previous communication [1].



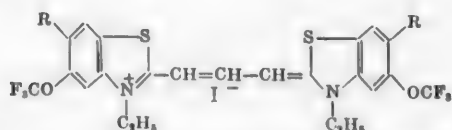
On diazotization and substitution by other groups, the latter amine (IV) yielded new bases, namely, 6-chloro-, 6-iodo- and 6-methylmercapto-5-trifluoromethoxy-2-methylbenzthiazoles. All the bases listed were converted into quaternary salts and thiocarbocyanines. The absorption maxima in alcohol of the cyanine dyes listed are given in the table; for comparison, data are also given on the absorption maxima of the corresponding dyes not containing trifluoromethoxy groups.

As the data in the table show, the OCF_3 groups in the 5,5'-positions in the benzthiazole nucleus have little effect on the absorption maximum of dyes with weakly electropositive substituents in the 6,6'-positions. As in the case of the corresponding methoxy derivatives [2], the trifluoromethoxy group and the adjacent substituent produce an additive shift in the absorption maximum of the dyes into the longer-wave part of the spectrum (the deviations were a total of 1-2 $\text{m}\mu$).

EXPERIMENTAL

2-Acetylamino-4-chloro-5-nitrophenyl trifluoromethyl ether (I) was obtained by nitration of acetylamino-4-chlorophenyl trifluoromethyl ether [1] and many recrystallizations of the product obtained, first from methyl alcohol and then from benzene. The m. p. was 111-112°.

Dyes



R	λ_{max} (in $\text{m}\mu$)	λ_{max} (in $\text{m}\mu$) of the analogous dye, not containing the OCF_3 group
H	561	558
Cl	566	561
I	573	571
SCH_3	585	580
NHCOCH_3	578	577
NH_2	595	594

2-Amino-4-chloro-5-nitrophenyl trifluoromethyl ether (II). 2.52 g of (I) was mixed with a solution of 0.76 g of potassium hydroxide in 6.5 ml of 75% alcohol, boiled for 15 minutes on a water bath and poured into water. The product was collected, washed with water and recrystallized from aqueous methyl alcohol. The yield was 1.88 g (86.7%). The m. p. was 88-89°.

Found %: N 10.63, 10.77. $\text{C}_7\text{H}_4\text{O}_3\text{N}_2\text{ClF}_3$.
Calculated %: N 10.91.

2,5-Diamino-4-chlorophenyl trifluoromethyl ether (III). 2 g of (II) was dissolved in 25 ml of alcohol and reduced with a solution of 7 g of stannous chloride in 14 ml of concentrated hydrochloric acid. The product was recrystallized from aqueous methyl alcohol. The yield was 1.05 g (59.5%). The m. p. was 66-67°.

Found %: N 12.61, 12.66. $\text{C}_7\text{H}_6\text{ON}_2\text{ClF}_3$. Calculated %: N 12.37.

The diacetyl derivative had m. p. 239-240° (from ethyl alcohol).

Found %: N 8.74, 8.78. $\text{C}_{11}\text{H}_{10}\text{O}_3\text{N}_2\text{ClF}_3$. Calculated %: N 9.01.

1-Trifluoromethoxy-4-chloro-2,5-benzoquinone. To a solution of 1 g of (III) in 20 ml of 10% sulfuric acid at 4-5° was gradually added a solution of 0.6 g of sodium bichromate in 14 ml of water, the mixture left over night, the product extracted with ether, the ether evaporated and the product recrystallized from petroleum ether. After sublimation, the yield was 0.2 g (20%). The m. p. was 107-108°.

Found %: F 25.30, 25.46. $\text{C}_7\text{H}_2\text{O}_3\text{ClF}_3$. Calculated %: F 25.12.

5-Trifluoromethoxy-6-amino-2-methylbenzthiazole (IV) was obtained according to [1] and had m. p. 94-95°; the acetyl derivative melted at 205-206°.

5-Trifluoromethoxy-6-chloro-2-methylbenzthiazole. 2.3 g of (IV) was dissolved in 6 ml of hydrochloric acid (d 1.19) and diazotized at 0° with a solution of 0.66 g of sodium nitrite in 4.5 ml of water. A cooled solution of 1 g of cuprous chloride in 6 ml of hydrochloric acid (d 1.19) was added and the mixture left overnight. The reaction mixture was then heated to 60°, made alkaline with sodium carbonate and steam distilled. The product was collected and recrystallized from aqueous methyl alcohol. The yield was 1.4 g (56.4%). The m. p. was 87-88°.

Found %: N 5.48, 5.57. $C_9H_5ONSClF_3$. Calculated %: N 5.24.

5-Trifluoromethoxy-5-iodo-2-methylbenzthiazole. 2.3 g of (IV) was dissolved in 4 ml of hydrochloric acid (d 1.19) and diazotized at 0° with a solution of 0.66 g of sodium nitrite in 3 ml of water. The excess sodium nitrite was destroyed by the addition of urea and then a solution of 2.3 g of potassium iodide in 3 ml of water added. The product was steam distilled. The yield was 1.15 g (30.3%). The m. p. was 95-96° (from aqueous methyl alcohol).

Found %: I 34.95, 35.07. $C_9H_5ONSF_3I$. Calculated %: I 35.37.

5-Trifluoromethoxy-6-methylmercapto-2-methylbenzthiazole. 2 g of (IV) was dissolved in 15 ml of water and 2 ml of hydrochloric acid (d 1.19) and diazotized with a solution of 0.6 g of nitrite in 2 ml of water. The solution of diazonium salt was treated with 2.1 g of sodium acetate and carefully poured with stirring into a solution of 1.62 g of sodium xanthate in 8 ml of water heated to 70°. The orange-red oil formed was extracted with ether and dried. The ether was evaporated. Alcoholic alkali (2 g of potassium hydroxide in 20 ml of alcohol) was added and the mixture boiled for 3 hours. The alcohol was removed in a water-pump vacuum. The product was dissolved in 15 ml of water and 1 ml of dimethyl sulfate added. The mixture was shaken for 30 minutes. On the following day the precipitate was collected, washed with water, dissolved in 20% hydrochloric acid, boiled with charcoal, the charcoal filtered off and the base precipitated with ammonia. The yield was 1.12 g (50%). The m. p. was 84-85°.

Found %: N 4.90, 5.06. $C_{10}H_9ONS_2F_3$. Calculated %: N 5.02.

Ethiodide of 5-trifluoromethoxy-6-iodo-2-methylbenzthiazole. 0.5 g of 5-trifluoromethoxy-6-iodo-2-methylbenzthiazole and 0.4 g of the ethyl ester of p-toluenesulfonic acid were heated for 4 hours at 140-150°. The product was washed with ether, dissolved in water, filtered and the ethiodide precipitated with a saturated solution of potassium iodide. The yield was 0.6 g (83.3%). The other quaternary salts were prepared similarly.

Dyes

6,6'-Dichloro-5,5'-ditrifluoromethoxy-3,3'-diethylthiacarbocyanine iodide. 0.2 g of the ethyltosylate of 2-methyl-5-trifluoromethoxy-6-chlorobenzthiazole, 0.2 g of orthoformic ester and 2 ml of acetic anhydride were boiled together for 1 hour. The dye was precipitated with ether, dissolved in alcohol and converted into the iodide by the addition of an aqueous solution of potassium iodide. The product was recrystallized from alcohol. The yield was 0.08 g (50%). The decomp. p. was 267-269°.

Found %: I 17.50, 17.61. $C_{23}H_{17}O_2N_2S_2Cl_2F_6I$. Calculated %: I 17.42.

6,6'-Diiodo-5,5'-ditrifluoromethoxy-3,3'-diethylthiacarbocyanine iodide. 0.25 g of the ethiodide of 2-methyl-5-trifluoromethoxy-6-iodobenzthiazole, 0.25 g of orthoformic ester and 1 ml of acetic anhydride were boiled for 1 hour. The dye was recrystallized from alcohol. The yield was 0.15 g (68.2%). The decomp. p. was 248-250°.

Found %: I 41.26, 41.39. $C_{23}H_{17}O_2N_2S_2F_6I_3$. Calculated %: I 41.77.

6,6'-Dimethylmercapto-5,5'-ditrifluoromethoxy-3,3'-diethylthiacarbocyanine iodide. A mixture of 0.3 g of the ethyltosylate of 2-methyl-5-trifluoromethoxy-6-methylmercaptobenzthiazole, 0.3 g of orthoformic ester, 2 ml of pyridine and 2 drops of acetic anhydride was boiled for 1 hour. The dye was precipitated with ether and converted to the iodide. It was recrystallized from alcohol. The yield was 0.12 g (50%). The m.p. was 268-270°.

Found %: I 16.63, 17.0. $C_{25}H_{23}O_2N_2S_4F_6I$. Calculated %: I 16.88.

6,6'-Diacetylamino-5,5'-ditrifluoromethoxy-3,3'-diethylthiacarbocyanine iodide. 0.2 g of the ethyltosylate of 2-methyl-5-trifluoromethoxy-6-acetylamino benzthiazole, 0.2 g of orthoformic ester, 2 g of pyridine and 2 drops of acetic anhydride were boiled for 45 minutes. The precipitated dye was collected and converted into the iodide. The product was recrystallized from alcohol. The yield was 0.1 g (62.5%). The m.p. was 273-275°.

Found %: I 16.33, 16.52. $C_{27}H_{25}O_4N_4S_2F_6I$. Calculated %: I 16.41.

The 6,6'-diamino compound was obtained by heating the diacetyl derivative with hydrochloric acid (d 1.19) on a boiling water bath and precipitating the dye with aqueous ammonia. The dye was dissolved in alcohol, an aqueous solution of potassium iodide added and the precipitated dye recrystallized from alcohol.

Found %: I 18.07, 1814. $C_{22}H_{21}O_2N_4S_2F_6L$ Calculated %: I 18.40.

SUMMARY

6-Amino-, 6-acetylamino-, 6-chloro-, 6-iodo- and 6-methylmercapto-5-trifluoromethoxy-2-methylbenzthiazoles were synthesized. Quaternary salts and symmetrical thiocarbocyanines were prepared from the bases listed. It was found that the trifluoromethoxy group in the 5,5'-positions of the benzthiazole nucleus had little effect on the absorption maxima of dyes containing weakly electropositive substituents in the 6,6'-positions.

LITERATURE CITED

- [1] L. M. Yagupol'skii and V. I. Troitskaya, J. Gen. Chem. 27, 518 (1957).*
- [2] I. I. Levkoev, N. N. Sveshnikov, I. N. Gorbacheva, and A. F. Vompe, Trans. Motion Picture and Photography Scientific Research Institute, 1944, No. 7, 29; I. I. Levkoev, N. N. Sveshnikov, and I. S. Barvyn', Proc. Acad. Sci., USSR, 85, 805 (1952).
- [3] I. I. Levkoev, N. N. Sveshnikov, I. N. Gorbacheva, N. S. Barvyn', and T. V. Krasnova, J. Gen. Chem. 24, 280 (1954).*

Received March 6, 1958

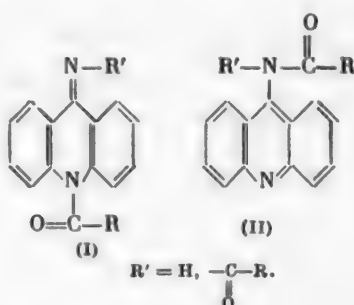
*Original Russian pagination. See C.B. Translation.

THE ABSORPTION SPECTRA AND STRUCTURE OF ACYL DERIVATIVES OF 9-AMINOACRIDINE

A. K. Sukhomlinov and V. I. Bliznyukov

Kharkov Pharmaceutical Institute

A study of certain properties of acyl derivatives of 9-aminoacridine has served as a basis for assigning imino-form structures of them [1, 2].



According to other data [3, 4], the mono- and diacyl derivatives of 9-aminoacridine should be considered as derivatives at the 9-amino group (II). Determination of the dipole moment did not throw light on this problem since the values of the vector sums for the imino form and the amino form of the diacetyl derivative of 9-aminoacridine are almost identical [5].

In order to throw further light on the structure of the acyl derivatives of 9-aminoacridine, we measured the ultraviolet absorption spectra of 9-aminoacetylaminacridine,* 9-diacetylaminacridine, 9-acetylbutyrylaminoacridine* and 9-propionylacetylaminacridine.*

9-Diacetylaminacridine was obtained by heating 9-aminoacridine with excess acetic anhydride [1].** After recrystallization from 50% aqueous ethanol, the almost colorless crystals had m. p. 148° (148-149° [1], 164° [3], 268° [5]). 9-Monoacetylaminacridine, 9-acetylbutyrylaminoacridine and 9-propionylacetylaminacridine agreed with literature data in melting point [1, 6].

The ultraviolet spectra in hexane, dioxane, ethanol, chloroform, dichloroethane, ethanol solutions of hydrogen chloride and 60% perchloric acid were studied. With all the solvents, investigations were made in the concentration range $10^{-3} - 10^{-5}$ M.

In all the solvents listed, the absorption spectra of 9-monoacetylaminacridine were characterized by two bands at λ_{\max} 3600 and 2500 Å (Fig. 1, curve 1).

The spectra of the diacyl derivatives in neutral solvents in the long-wave region of the ultraviolet showed

* Samples of the preparations were kindly presented for the spectrographic investigation by A. M. Grigorovskii.

** L. Vodyanitskaya and L. Dolbik participated in the investigation.

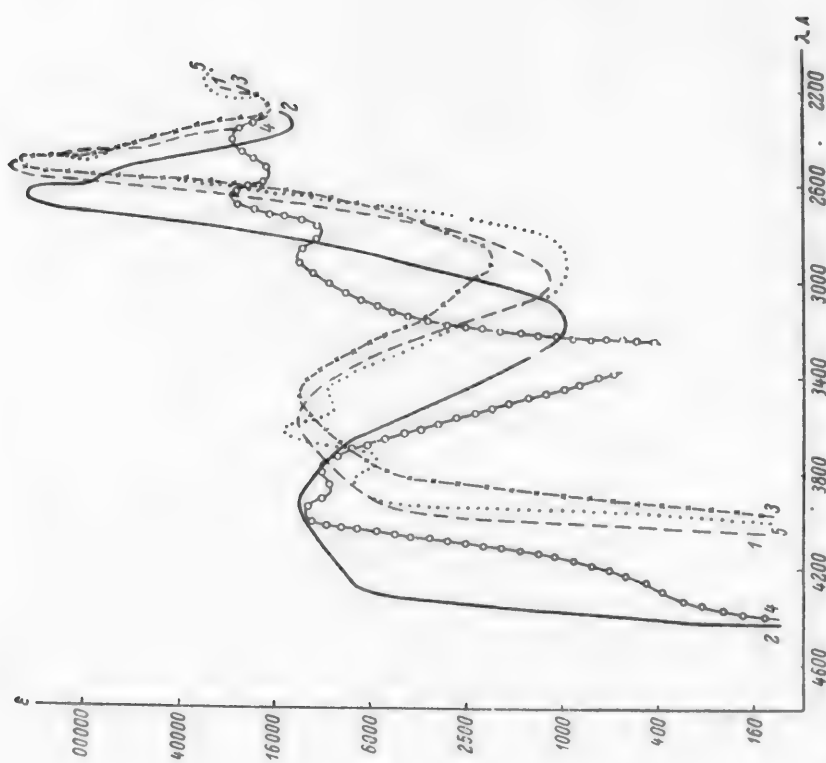


Fig. 1. Absorption spectra. 1) 9-monoacetylaminocridine in dioxane, 2) 9-aminoacridine in dioxane, 3) acridine in dioxane, 4) N-methyl-9-iminoacridine in dioxane, 5) 9-diacetylaminocridine in dioxane.

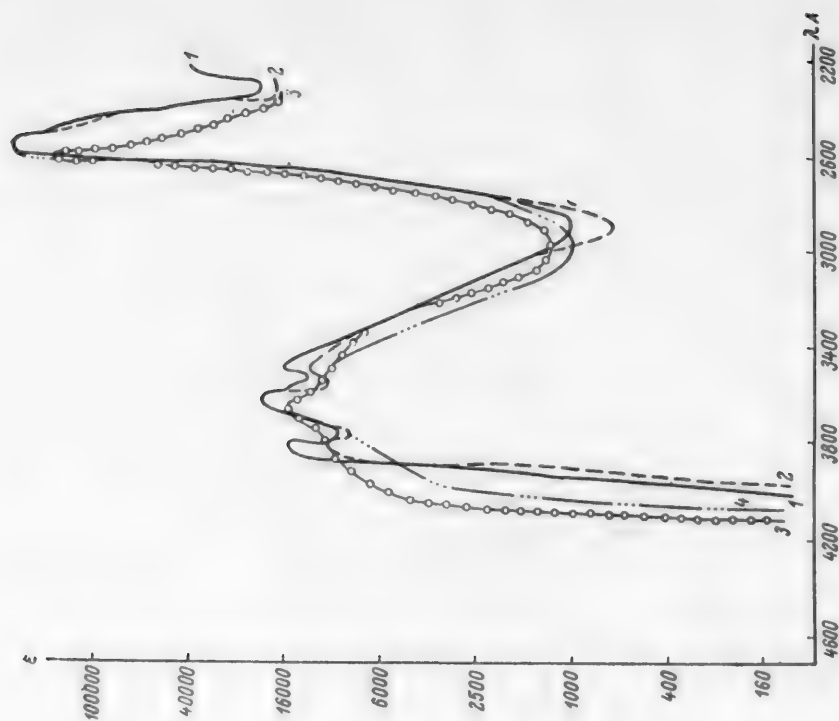


Fig. 2. Absorption spectra. 1) 9-diacetylaminocridine in hexane, 2) 9-acetylburyrylaminoacridine in hexane, 3) 9-acetylburyrylaminoacridine in ethanol, 4) 9-propionylacetylaminocridine in ethanol.

three absorption bands in dioxane or hexane (Fig. 1, curve 5; Fig. 2, curves 1 and 2), which merged into one broad band with a general maximum at λ 3630 Å (Fig. 2, curves 3 and 4) on going to ethanol. In neutral solvents and in the short-wave ultraviolet, a single narrow band at λ_{max} 2500 Å was observed.

Comparison of the absorption curves of 9-aminoacridine, its acyl derivatives and acridine in dioxane and also other neutral solvents (Fig. 1, curves 1-3; Fig. 2, curves 1-4) showed that replacement of the hydrogen of the amino group by an acid residue produced a shift in the longwave band towards shorter wavelengths of 400 Å and in the short-wave band of 200 Å. The absorption curves of 9-monoacetylaminacridine and also

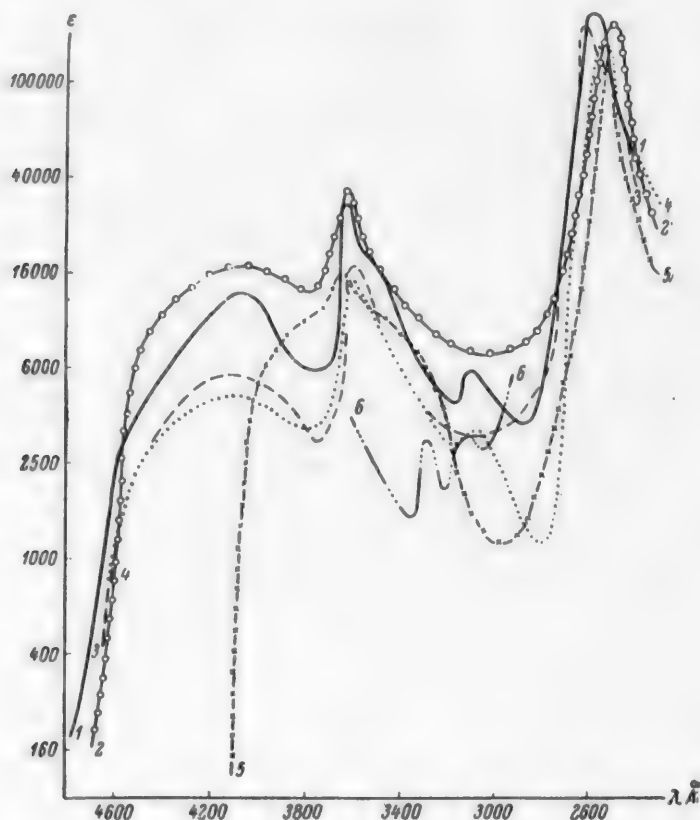


Fig. 3. Absorption spectra. 1) 9-monoacetylaminacridine in 5 M ethanol solution of HCl, 2) 9-acetylbutyrylaminoacridine in 5 M ethanol solution of HCl, 3) 9-diacetylaminacridine in 5 M ethanol solution of HCl, 4) 9-monoacetylaminacridine in ethanol solution of HCl (molar ratio of 1 : 100), 5) 9-acetylbutyrylaminoacridine in ethanol, 6) 9-aminoacridine in ethanol solution of HCl (molar ratio of 1 : 100), part of curve.

of the diacetyl derivatives were similar to the curve of unsubstituted acridine, indicating that they have amine and not imine structures. Had the acyl residue been on the ring nitrogen, then the spectra must have shown a "quinonimine" band at λ_{max} 2900 Å, as was previously noted for 10-methyl-9-iminoacridine [7] (Fig. 1, cf. curves 1 and 4). It should be noted that similar optical properties were noted for the mono- and diacetyl derivatives of 9-aminoanthracene [8] when compared with anthracene and 9-aminoanthracene.

With salt formation, for example in ethanol solutions of hydrogen chloride, the absorption spectra of 9-monoacetylaminacridine were shifted towards longer wavelengths (Fig. 3, curves 1, 4, cf. with 5) and became similar to the spectrum of the acridinium ion [9]. This similarity also indicates that the acetyl residue is at

the 9-amino group and salt formation occurred at the ring nitrogen. In addition, under the action of ethanol solutions of hydrogen chloride, the spectral curve of 9-monoacetylaminocridine (Fig. 3, curves 1 and 4, cf. with 6) shows an absorption band at λ_{\max} 3100 Å. From its origin, it can be treated as a "pyridine" absorption band of 9-aminoacridine derivatives [7]. The absorption spectra of the diacyl derivatives of 9-aminoacridine changed similarly in ethanol solutions of hydrogen chloride* (Fig. 3, curves 2 and 3) with the

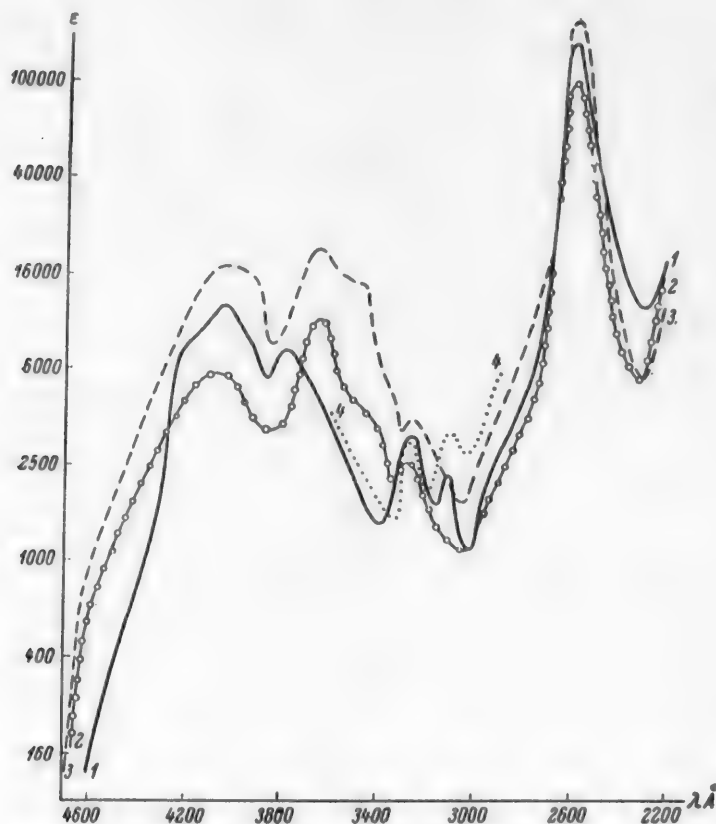


Fig. 4. Absorption spectra. 1) 9-acetylbutyraminoacridine in 60% HClO_4 , 2) 9-diacetylaminocridine in 60% HClO_4 , 3) 9-aminoacetylaminocridine in 60% HClO_4 , 4) 9-aminoacridine in ethanol solution of HCl (molar ratio of 1 : 100), part of curve.

difference that the "pyridine" band at λ_{\max} 3100 Å was not observed. In 60% perchloric acid, the absorption spectra of the mono- and diacyl derivatives of 9-aminoacridine showed a "pyridine" band (Fig. 4, curves 1-3, cf. with 4).

Thus the absence of "quinonimine" absorption bands in neutral solvents and, on the other hand, the presence of "pyridine" absorption bands in acid solutions in the spectra of mono- and diacyl derivatives of 9-aminoacridine indicate that the monoacyl and diacyl derivatives should be considered as derivatives of the amino form.

* It should be recorded that in 5 M hydrogen chloride, partial hydrolysis of the diacyl derivatives of 9-aminoacridine occurred with the formation of monoacyl derivatives, as indicated by an increase in the melting point of the crystals isolated after neutralization of the acid.

SUMMARY

1. A study was made of the absorption spectra of 9-monoacetylaminoacridine, 9-diacetylaminoacridine, 9-propionylacetylaminoacridine and 9-acetylbutyrylaminoacridine.
2. It was shown that according to the absorption spectra, all these compounds are derivatives of the amino form of 9-aminoacridine.

LITERATURE CITED

- [1] A. M. Grigorovskii, Proc. Acad. Sci. USSR, 53, 233 (1946).
- [2] A. M. Grigorovskii, Prog. Chem. 21, 615 (1952).
- [3] J. H. Wilkinson and J. L. Finar, J. Chem. Soc., 1946, 115.
- [4] A. Albert and B. Ritchie, J. Chem. Soc., 1943, 458.
- [5] Z. V. Pushkareva and Z. Yu. Kokoshko, Proc. Acad. Sci. USSR, 93, 77 (1953).
- [6] A. M. Grigorovskii, Diss.: "Investigations in the Field of Acridine Derivatives". Moscow (1951).*
- [7] A. K. Sukhomlinov, J. Gen. Chem. 28, 1038 (1958).*
- [8] A. S. Cherkasov, Bull. Acad. Sci. USSR, Phys. Ser., 20, 478 (1956).
- [9] V. I. Bliznyukov and A. K. Sukhomlinov, J. Gen. Chem. 28, 1247 (1958).*

Received February 26, 1958

*In Russian.

**Original Russian pagination. See C.B. Translation.

REACTION OF β -CHLOROVINYL KETONES WITH β -DICARBONYL COMPOUNDS

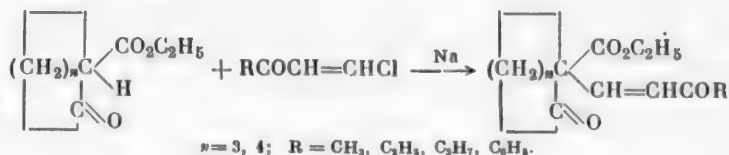
IX. KETOVINYLATION OF ESTERS OF CYCLIC β -KETO ACIDS

N. K. Kochetkov, B. P. Gottikh, and Rol'f Shtumpf

Institute of Pharmacology and Chemotherapy, Academy of Medical Sciences, USSR

As was shown in previous communications, metal derivatives of β -dicarbonyl compounds, malonic ester [1], alkylmalonic esters [2] and α -alkylacetoacetic esters [3], react with β -chlorovinyl ketones to form ketovinylation products. Since certain conversions of the latter which we studied [4, 5] showed that they were of considerable interest in synthetic organic chemistry, it was desirable to enlarge the scope of the ketovinylation reaction and then extend it to other β -dicarbonyl compounds. In this article we report on the ketovinylation of esters of cyclic β -keto acids, which opens up new synthetic possibilities. As examples for the investigation we used the ethyl esters of cyclopentanone- and cyclohexanonecarboxylic acids, which contain one active hydrogen and therefore must undergo ketovinylation without any complications (cf. [6]).

These β -keto esters were ketovinylated under conditions developed previously for alkylmalonic and α -alkylacetoacetic esters [2, 3], i.e., by reaction of a benzene suspension of the sodio derivative of the β -keto ester with the β -chlorovinyl ketone. In all cases the reaction proceeded smoothly both for alkyl β -chlorovinyl ketones and for their aromatic analogs; normal ketovinylation products were formed in yields of 60-70%.

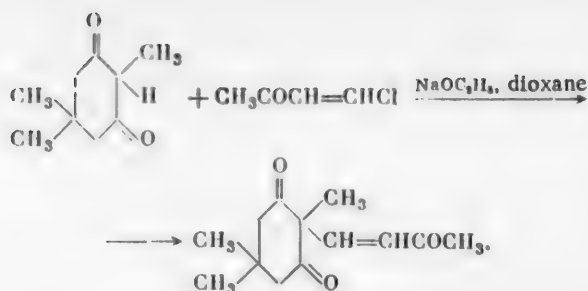


After the normal processing, 1-carbethoxy-1-(3'-ketoalken-1'-yl-1')-cycloalkanones-2 were isolated by distillation, with the exception of 1-carbethoxy-1-(phenylpropen-1'-on-3'-yl-1')-cyclohexanone-2 (see Experimental).

Since the compounds obtained did not form 1,3,5-triacylbenzenes on treatment with dilute acids in the cold, their structure was undoubtedly that of C-ketovinylation products and this reaction did not differ in principle from the ketovinylation of α -alkylacetoacetic esters [3].

In order to determine the possibility of ketovinylating other β -dicarboxylic compounds of the alicyclic series, we investigated the ketovinylation of a cyclic β -diketone, namely 1,1,4-trimethylcyclohexanedione-3,5 (methyldimedone). In accomplishing this reaction, we encountered a series of experimental difficulties, connected with the preparation of the sodio derivative of methyldimedone. After a series of experiments we found conditions under which it was possible to obtain the ketovinylation product of methyldimedone in 30-35% yield.

When hydrogenated over palladium, this product absorbed 1 mole of hydrogen, indicating the presence of one double bond in it and it did not give 1,3,5-triacetylbenzene when treated with dilute acids; this indicates



that the ketovinylation product was a C-derivative. These facts confirm the structure of the substance obtained and demonstrate in principle the possibility of using the ketovinylation reaction for cyclic β -diketones, widening its use in the allicyclic series.

EXPERIMENTAL

1-Carbethoxy-1-(3'-ketobutenyl-1')-cyclopentanone-2. 5 g of finely divided sodium was suspended in 200 ml of anhydrous benzene, the suspension heated to boiling and 34.5 g of 1-carbethoxycyclopentanone-2 added with stirring over a period of 1-1.5 hours, after which the reaction mixture was boiled for a further 4-5 hours so that the sodium reacted completely. At room temperature and over a period of 20-30 minutes, a solution of 20 g of methyl β -chlorovinyl ketone in 20 ml of absolute benzene was added to the sodio derivative of carbethoxycyclopentanone obtained, then the reaction mixture was slowly heated to boiling, boiled for 2.5-3 hours, cooled to room temperature and the benzene solution washed with water (2×150 ml). The wash waters were extracted with benzene, which was added to the main portion and the solvent removed. The residue was vacuum distilled and a fraction with b. p. $146-151^\circ$ (3 mm) collected. After three distillations, the substance had b. p. $147-149^\circ$ (3 mm), d_{20}^{20} 1.1112, n_D^{20} 1.4880, M_R^D 58.14; calc. 56.62. The yield was 28 g (65%). The yellowish liquid had a characteristic smell and was stable to storage.

Found %: C 64.41, 64.68; H 7.35, 7.52. $\text{C}_{12}\text{H}_{18}\text{O}_4$. Calculated %: C 64.28; H 7.19.

1-Carbethoxy-1-(3'-ketopenten-1'-yl-1')-cyclopentanone-2 was obtained analogously from 34.5 g of 1-carbethoxycyclopentanone-2, 23 g of ethyl β -chlorovinyl ketone and 5 g of sodium. A fraction with b. p. $155-161^\circ$ (4 mm) was collected during vacuum distillation. After three distillations the substance had b. p. $153-155^\circ$ (3 mm), d_{20}^{20} 1.0958, n_D^{20} 1.4862, M_R^D 62.68; calc. 61.24. The yield was 29 g (64%). The yellowish liquid had a characteristic smell and was stable to storage.

Found %: C 65.72, 65.86; H 7.81, 7.87. $\text{C}_{13}\text{H}_{20}\text{O}_4$. Calculated %: C 65.53; H 7.62.

1-Carbethoxy-1-(3'-ketohepten-1'-yl-1')-cyclopentanone-2 was obtained analogously from 34.5 g of carbethoxycyclopentanone, 25 g of propyl β -chlorovinyl ketone and 5 g of sodium. A fraction with b. p. $158-165^\circ$ (3 mm) was collected during vacuum distillation. After three distillations, the substance had b. p. $149-152^\circ$ (2 mm), d_{20}^{20} 1.0767, n_D^{20} 1.4840, M_R^D 67.09; calc. 65.86. The yield was 33.5 g (67%). The yellowish liquid had a characteristic smell and was stable to storage.

Found %: C 66.54, 66.61; H 7.98, 8.18. $\text{C}_{14}\text{H}_{22}\text{O}_4$. Calculated %: C 66.63; H 7.98.

1-Carbethoxy-1-(3'-phenylpropen-1'-on-3'-yl-1')-cyclopentanone-2 was obtained analogously from 34.5 g of carbethoxycyclopentanone, 32 g of phenyl β -chlorovinyl ketone and 5 g of sodium. The residue after removal of the solvent was distilled in a vacuum of 0.03 mm and a fraction collected at a bath temperature of $154-156^\circ$. After standing for a month, the substance had crystallized completely and had m. p. $60-65^\circ$. The yield was 27 g (49%). The colorless crystals were stable to storage.

Found %: C 71.60, 71.71; H 6.48, 6.54. $\text{C}_{17}\text{H}_{18}\text{O}_4$. Calculated %: C 71.33; H 6.68.

1-Carbethoxy-1-(3'-ketobutenyl-1')-cyclohexanone-2 was obtained analogously from 37.5 g of carbethoxycyclohexanone, 20 g of methyl β -chlorovinyl ketone and 5 g of sodium. A fraction with b. p. $163-166^\circ$

(4 mm) was collected during vacuum distillation. The twice distilled substance was left in a refrigerator overnight, when it crystallized completely and had m. p. 28.5-29°. The yield was 28 g (64%). The colorless crystals had a characteristic smell and were stable to storage.

Found %: C 65.72, 65.67; H 7.40, 7.48. $C_{13}H_{18}O_4$. Calculated %: C 65.53; H 7.61.

1-Carboethoxy-1-(3'-ketohehexen-1'-yl-1')-cyclohexanone-2 was obtained analogously from 37.5 g of carbethoxycyclohexanone, 25 g of propyl β -chlorovinyl ketone and 5 g of sodium. A fraction with b. p. 165-169° (2 mm) was collected during vacuum distillation. After three distillations, the substance had b. p. 168-169° (2 mm), d_4^{20} 1.0722, n_D^{20} 1.4868, M_R 71.58; calc. 70.48. The yield was 32 g (61%). The yellowish liquid had a characteristic smell and was stable to storage.

Found %: C 67.90, 67.82; H 8.51, 8.52. $C_{15}H_{22}O_4$. Calculated %: C 67.72; H 8.33.

1-Carboethoxy-1-(3'-phenylpropen-1'-on-3'-yl-1')-cyclohexanone-2 was obtained analogously from 30 g of carbethoxycyclohexanone, 27 g of phenyl β -chlorovinyl ketone and 4 g of sodium. After removal of the solvent, the residue crystallized on cooling. If crystallization did not begin, it was produced by grinding in the cold with alcohol or ether. Two recrystallizations from a mixture of anhydrous alcohol and ether (1 : 2) gave 29.7 g (65%) of a substance with m. p. 72-73°. The colorless crystals were soluble in alcohol and acetone and stable to storage.

Found %: C 71.89, 71.99; H 6.94, 6.89. $C_{18}H_{20}O_4$. Calculated %: C 71.98; H 6.71.

1,1,4-Trimethyl-4-(3'-ketobutenyl-1')-cyclohexanedione-3,5. To a solution of sodium ethylate prepared from 2.2 g of sodium in 30 ml of anhydrous alcohol was added a solution of 14 g of 1,1,4-trimethylcyclohexanedione-3,5 (methylidimedone) in 80 ml of anhydrous alcohol. About 80 ml of alcohol was distilled from the reaction mixture, 100 ml of dioxane added and 65-70 ml of a mixture of dioxane and alcohol distilled off. At room temperature and with vigorous stirring, a solution of 9.5 g of methyl β -chlorovinylketone in 50 ml of dioxane was added to the reaction mixture over a period of 15 minutes, the reaction mixture then heated to boiling, boiled for 2.5 hours and cooled to room temperature and the precipitate removed by filtration. The dioxane was evaporated from the filtrate and the residue, which formed a semicrystalline mass, treated with 25 ml of ether. The insoluble residue was filtered from the ether solution, the filtrate cooled in a mixture of dry ice and acetone and the crystalline material separated. The yield was 7 g (35%). After two recrystallizations from ether, the substance had m. p. 37-38° and b. p. 147-149° (2 mm). The colorless crystals had a pleasant smell and decomposed on storage. When they were stirred in the cold with dilute hydrochloric acid, 1,3,5-triacetylbenzene was not formed.

Found %: C 70.54, 70.65; H 8.35, 8.25. $C_{13}H_{18}O_3$. Calculated %: C 70.24; H 8.16.

1,1,4-Trimethyl-4-(3'-ketobutyl-1')-cyclohexanedione-3,5. 2.3 g of 1,1,4-trimethyl-4-(3'-ketobutenyl-1')-cyclohexanedione-3,5 in 40 ml of anhydrous alcohol was hydrogenated over palladium on barium sulfate. Over a period of 0.5 hours, 250 ml of hydrogen (20°, 753 mm; 252 ml required according to calculation) was absorbed. After the usual processing, vacuum distillation yielded a fraction with b. p. 128-131° (1 mm). The yield was 2 g (86%). Immediately after distillation the substance had n_D^{20} 1.4791. After standing for 1 year, the substance partially crystallized. The semicrystalline mass was colorless.

Found %: C 70.30; H 8.92. $C_{13}H_{20}O_3$. Calculated %: C 69.61; H 8.90.

SUMMARY

1. It was shown that esters of cyclic β -keto acids in the form of sodio derivatives react smoothly with β -chlorovinyl ketones by the general scheme for the ketovinylolation reaction, forming 1-carboethoxy-1-(3'-ketoalkenyl)-cycloalkanones-2 in yields of 60-70%.

2. The reaction of 1,1,4-trimethylcyclohexanedione-3,5 in the form of its sodio derivative with methyl β -chlorovinyl ketone to form 1,1,4-trimethyl-4-(3'-ketobutenyl)-cyclohexanedione-3,5 demonstrates the applicability of the ketovinylolation reaction to cyclic β -diketones.

LITERATURE CITED

- [1] N.K. Kochetkov and L. I. Kudryashov, J. Gen. Chem. 27, 248 (1957).*
- [2] N. K. Kochetkov and L. I. Kudryashov, J. Gen. Chem. 26, 851 (1956).*
- [3] N. K. Kochetkov, B. P. Gottikh, and L. I. Kudryashov, J. Gen. Chem. 28, 1508 (1958).*
- [4] N. K. Kochetkov, L. I. Kudryashov, and R. A. Aleeva, 27, 2166 (1957).*
- [5] N. K. Kochetkov and B. P. Gottikh, J. Gen. Chem. 28, 2732 (1958). *
- [6] N. K. Kochetkov, L. I. Kudryashov, and T. M. Senchenkova, J. Gen. Chem. 29, 650 (1959).*

Received March 6, 1958

*Original Russian pagination. See C.B. Translation.

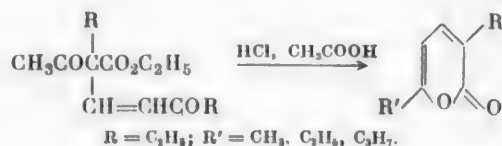
REACTION OF β -CHLOROVINYL KETONES WITH β -DICARBONYL COMPOUNDS

X. PREPARATION OF α -PYRONE DERIVATIVES FROM α -(3-KETOALKENYL-1)- β -KETO ACID

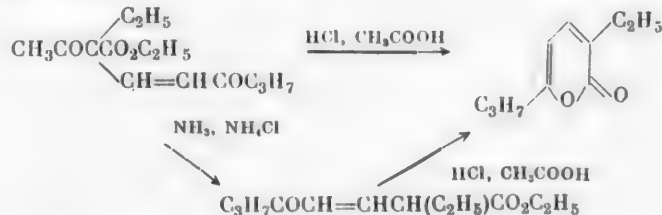
N. K. Kochetkov and B. P. Gottikh

Institute of Pharmacology and Chemotherapy, Academy of Medical Sciences, USSR

As we showed previously, the reaction of β -chlorovinyl ketones with α -alkylacetoacetic esters [1] and esters of cyclic β -keto acid [2] proceeds smoothly to give esters of the corresponding α -(3-ketoalkenyl-1)- β -keto acids. A study of the conversions of these readily available and reactive substances is interesting in connection with their use as a basis for new methods of synthesizing certain classes of compounds. We recently showed [3] that the ketovinylation products of α -alkylacetoacetic esters, α -alkyl- α -(3-ketoalkenyl-1)-acetoacetic esters, reacted with aqueous solutions of ammonia and ammonium chloride to lose an acetyl group and form vinylogs of esters of β -keto acids. We then made attempts to find conditions for ketonic cleavage of α -alkyl- α -(3-ketoalkenyl-1)-acetoacetic esters, which, however, have not been successful up to now. Thus, treatment of these compounds with aqueous solutions of alkalis at room temperature and also boiling with barium hydroxide solution gave a mixture of high-boiling, oily products, from which it was not possible to isolate individual substances. We then turned to a study of the behavior α -alkyl- α -(3-ketoalkenyl-1)-acetoacetic esters in the presence of acids; however, in this case ketonic cleavage was not observed, although the reaction gave a quite definite result and led to 3,6-dialkyl- α -pyrones.

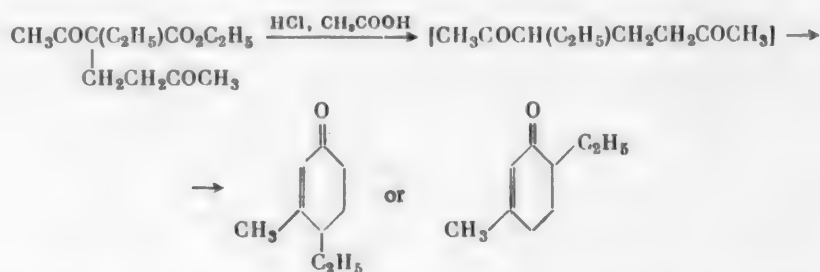


The reaction was most conveniently performed by heating the ketovinylated ester of the β -keto acid with a mixture of hydrochloric and acetic acids, which ensured a homogeneous reaction mixture and gave 65-70% yields. The structure of the compounds obtained was confirmed by direct synthesis of one of the substances obtained, 3-ethyl-6-propyl- α -pyrone, by cyclization of the ethyl ester of α -(3-ketohexen-1-yl-1)-butyric acid, which we described previously.

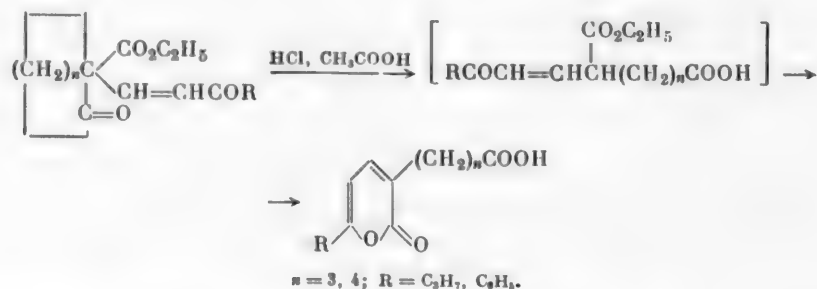


The structure of the conversion products of α -alkyl- α -(3-ketoalkenyl-1)-acetoacetic esters was also confirmed by the fact that when hydrogenated over palladium, they absorbed 2 moles of hydrogen (the hydrogenation proceeded very slowly) (see [4]), indicating the presence of two double bonds. Thus, treatment of α -alkyl- α -(3-ketoalkenyl-1)-acetoacetic esters with acids produced acid cleavage, accompanied by cyclization of the ester of the unsaturated δ -keto acid formed into an α -pyrone derivative. The latter stage of the reaction was quite analogous to the cyclization of 3-ketoalkenylmalonic esters into α -pyrone-3-carboxylic acids, described recently by one of us and L. I. Kydryashov [5, 6].

The results presented indicate that under the action of acids, as on treatment with ammonia [3], α -alkyl- α -(3-ketoalkenyl-1) acetoacetic esters undergo cleavage with the elimination of an acetyl group. Since ketonic cleavage under the action of mineral acids is more characteristic of esters of β -keto acids, including α, α -disubstituted acetoacetic esters, apparently, in this case, the determining effect on the direction of the reaction is the presence of the ketovinyl group, which (in accordance with the principles of vinology) is similar to an acyl group. Actually, when the reaction was carried out under the same conditions with a saturated analog of the compounds described, α -ethyl- α -(3-ketobutyl-1)-acetoacetic ester, from which the ketoalkenyl group is absent, a normal ketonic cleavage reaction was observed and the δ -diketone formed then cyclized into a dialkylcyclohexenone.



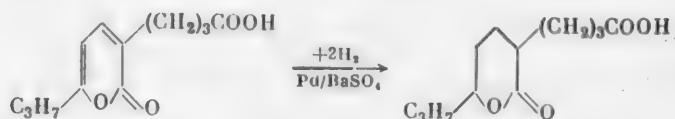
The predominant acid cleavage of esters of α -ketoalkenyl- β -keto acids and subsequent cyclization was then used by us for synthesizing the previously unknown ω -(α -pyronoyl)-carboxylic acids. For this, we reacted the ketovinylation products of esters of cyclic β -keto acids under the conditions described above [2]. Heating 1-carbethoxy-1-(3'-ketohehexen-1'-yl-1')-cyclopentanone-2 and 1-carbethoxy-1-(3'-phenylpropen-1'-on-3'-yl-1')-cyclohexanone-2 in a mixture of hydrochloric and acetic acids yielded γ -(6-propyl- α -pyronoyl-3)-butyric and δ -(6-phenyl- α -pyronoyl-3)-valeric acids, respectively.



As we showed in the example of 1-carbethoxy-1-(3'-phenylpropen-1'-on-3'-yl-1')-cyclohexanone-2, similar conversions of ketovinylation carbethoxycycloalkanones proceed in even better yields on treatment of the latter with a 3% aqueous solution of sodium hydroxide at room temperature. The presence of the carboxyl group in the compounds synthesized was confirmed by titration results. The absorption of 2 moles of hydrogen during hydrogenation over palladium, which proceeded slowly, demonstrated the presence of an α -pyrone ring.

Data presented in this article shown that the conversions of ketovinylation products of esters of β -keto acids under the action of acid may serve as a quite general method of synthesizing various α -pyrone derivatives.

Previous work from our laboratory on the preparation of α -pyrone derivatives from ketovinylmalonic esters [5, 6] together with the data presented here indicates that the ketovinylation of malonic ester and esters of β -keto acids with subsequent cyclization of the reaction products is the most convenient method of synthe-



izing α -pyrones. The various α -pyrone derivatives, which thus become accessible, may in their turn serve as valuable starting materials for the synthesis of various compounds [7].

EXPERIMENTAL

3-Ethyl-6-methyl- α -pyrone. 36 g of α -ethyl- α -(3-ketobutenyl-1)-acetoacetic ester was boiled with a mixture of 80 ml of concentrated hydrochloric acid and 80 ml of glacial acetic acid for 3.5 hours. When the reaction mixture had cooled to room temperature, it was poured into 150 ml of water, the oil separated, and the aqueous layer carefully extracted with ether. The ether extracts were combined with the bulk of the substance, washed with 5-10% sodium carbonate solution, and then with water and dried with magnesium sulfate. After removal of the ether, the residue was vacuum distilled and a fraction collected with b. p. 112-118° (15 mm). The yield was 15.6 g (71%). After three distillations, the substance had b. p. 87-88° (4 mm), d_{20}^{20} 1.0643, n_D^{20} 1.5168. 3-Ethyl-6-methyl- α -pyrone was a colorless liquid with a characteristic smell and was stable to storage.

Found %: C 69.56, 69.68; H 7.48, 7.43. $C_9H_{10}O_2$. Calculated %: C 69.54; H 7.29.

3,6-Diethyl- α -pyrone was obtained similarly by boiling 30 g of α -ethyl- α -(3-ketopenten-1-yl-1)-acetoacetic ester with a mixture of 62.5 ml of concentrated hydrochloric acid and 60 ml of glacial acetic acid for 4 hours. Vacuum distillation yielded a fraction with b. p. 88-90° (3 mm). The yield was 12.8 g (67.5%). After 3 distillations, the substance had b. p. 74-76° (1 mm), d_{20}^{20} 1.0492, n_D^{20} 1.5105. The colorless liquid with a characteristic smell was stable to storage.

Found %: C 70.85, 70.76; H 8.02, 8.11. $C_9H_{12}O_2$. Calculated %: C 71.02; H 7.95.

3-Ethyl-6-propyl- α -pyrone. A. 31.7 g of α -ethyl- α -(3-ketohexen-1-yl-1)-acetoacetic ester was boiled with a mixture of 62.5 ml of concentrated hydrochloric acid and 100 ml of glacial acetic acid for 4 hours. After the processing described above, vacuum distillation yielded a fraction with b. p. 81-83° (1 mm). The yield was 16.1 g (71%). After 3 distillations the substance had b. p. 79-81° (1 mm), d_{20}^{20} 1.0167, n_D^{20} 1.5060.

B. 10.6 g of the ethyl ester of α -(3-ketohexen-1-yl-1)-butyric acid was boiled with a mixture of 20 ml of concentrated hydrochloric acid and 25 ml of glacial acetic acid for 3 hours. After the processing described, vacuum distillation gave a fraction with b. p. 91.5-93° (3 mm). The yield was 6 g (72%). After 3 distillations the substance had b. p. 79-81° (1 mm), d_{20}^{20} 1.0171, n_D^{20} 1.5073. It was a colorless liquid with a characteristic smell and was stable to storage.

Found %: C 72.43, 72.51; H 8.79, 8.72. $C_{10}H_{14}O_2$. Calculated %: C 72.26; H 8.48.

Lactone of α -ethyl- δ -hydroxycaprylic acid. 7.5 g of 3-ethyl-6-propyl- α -pyrone was hydrogenated at room temperature in 40 ml of dry acetone over palladium on barium sulfate. Over a period of a day, 2110 ml of hydrogen was absorbed (2120 ml required by calculation). The usual processing and vacuum distillation yielded 7.1 g (90%) of a substance with b. p. 87-89° (1 mm). After 3 distillations, the substance had b. p. 83.5-85.5° (1 mm), d_{20}^{20} 0.9796, n_D^{20} 1.4550. The colorless liquid was stable to storage.

Found %: C 71.26, 71.21; H 10.76, 10.75. $C_{10}H_{18}O_2$. Calculated %: C 70.54; H 10.65.

3-Methyl-4-(or 6)-ethylcyclohexen-3-one-1. 21 g of α -ethyl- α -(3-ketobutyl-1)-acetoacetic ester was boiled with a mixture of 26.5 ml of concentrated hydrochloric acid and 26.5 ml of glacial acetic acid for 3.5 hours. After the processing described above, vacuum distillation gave a fraction with b. p. 80-82° (5 mm).

The yield was 5.9 g (80%). After 3 distillations, the substance had b. p. 74-74.5° (4 mm), d_4^{20} 0.9429, n_D^{20} 1.4848. The colorless liquid had a characteristic smell and was stable to storage.

Found %: C 78.58, 78.59; H 10.35, 10.49. $C_9H_{14}O$. Calculated %: C 78.21; H 10.24.

The 2,4-dinitrophenylhydrazone formed dark red crystals with m. p. 113-115° (from anhydrous alcohol).

Found %: N 17.71, 17.54. $C_{15}H_{20}O_4N_4$. Calculated %: N 17.60.

γ -(6-Propyl- α -pyronoyl-3)-butyric acid. 25.2 g of 1-carbethoxy-1-(3'-ketohehexen-1'-yl-1')-cyclopentanone-2 was boiled with a mixture of 50 ml of concentrated hydrochloric acid and 55 ml of glacial acetic acid for 4.5 hours. After the processing described above, vacuum distillation gave a fraction with b. p. 195-206° (2 mm). The yield was 12.5 g (56%). After repeated distillation, the substance had b. p. 195-200° (2 mm), n_D^{20} 1.5232.

Found %: C 64.70, 64.75; H 7.43, 7.48. $C_{12}H_{16}O_4$. Calculated %: C 64.27; H 7.19.

The thick, yellowish oil was stable to storage.

δ -(6-Phenyl- α -pyronoyl-3)-valeric acid. A. 3 g of 1-carbethoxy-1-(3'-phenylpropen-1'-on-3'-yl-1')-cyclohexanone-2 was boiled with a mixture of 5 ml of concentrated hydrochloric acid and 10 ml of glacial acetic acid for 3 hours. When the mixture had been cooled to room temperature, it was poured into 75 ml of water. The precipitate was collected by filtration, washed with warm ether and dried in a vacuum desiccator over alkali and paraffin. The yield was 0.65 g (24%). The substance had m. p. 159-161°.

Found %: C 70.84, 70.77; H 6.31, 6.22. $C_{16}H_{16}O_4$. Calculated %: C 70.54; H 5.92.

B. 8 g of 1-carbethoxy-1-(3'-phenylpropen-1'-on-3'-yl-1')-cyclohexanone-2 was stirred with 40 ml of a 3% aqueous solution of sodium hydroxide at room temperature for 19-20 hours and the undissolved residue removed by filtration. The filtrate was acidified to pH 3 with 10% hydrochloric acid. The precipitate was collected, washed with water and warm ether and then dried in a vacuum desiccator over alkali and paraffin. The yield was 4.6 g (63%). The substance had m. p. 159-161°. A mixed melting point with the substance from experiment A was not depressed. The colorless powder was soluble in acetone and alcohol and stable to storage.

Found %: C 70.16, 70.38; H 6.09, 6.03. M 256.2, 271.0 (by titration with NaOH). $C_{16}H_{16}O_4$.
Calculated %: C 70.54; H 5.92. M 272.3.

δ -Lactone of α -(3-hydroxyhexyl)-adipic acid. 5 g of γ -(6-propyl- α -pyronoyl-3)-butyric acid was hydrogenated at room temperature in 40 ml of dry acetone over palladium on barium sulfate. Over a period of 2 days, 1120 ml of hydrogen was absorbed (1000 ml required by calculation). The usual processing and removal of the solvent yielded a solid residue, which was reprecipitated from benzene with petroleum ether. The yield was 4.2 g (82.5%). After a second reprecipitation, substance had m. p. 50-51.5°. The colorless crystals were readily soluble in many organic solvents. The substance was stable to storage.

Found %: C 63.42, 63.45; H 9.22, 9.12. $C_{12}H_{20}O_4$. Calculated %: C 63.13; H 8.83.

SUMMARY

1. It was shown that treatment of α -alkyl- α -(3-ketoalkenyl)-acetoacetic esters with a mixture of hydrochloric and acetic acids produced acid cleavage with subsequent cyclization of the esters of unsaturated δ -keto acids into 3,6-disubstituted α -pyrones and this process may be used as a method for synthesis of the latter (yields, 65-70%).

2. Under the same conditions or under the action of dilute aqueous solutions of sodium hydroxide, 1-carbethoxy-1(3'-ketoalkenyl)-cycloalkanones-2 gave ω -[6-alkyl(aryl)- α -pyronoyl-3]-alkanecarboxylic acids.

LITERATURE CITED

[1] N. K. Kochetkov, B. P. Gottikh, and L. I. Kudryashov, J. Gen. Chem. 28, 1508 (1958).*

[2] N. K. Kochetkov, B. P. Gottikh, and P. Shtumpf, J. Gen. Chem. 29, 1320 (1959).*

* Original Russian pagination. Sec C.B. Translation.

- [3] N. K. Kochetkov and B. P. Gottikh, J. Gen. Chem. 28, 2732 (1958).*
- [4] N. K. Kochetkov and L. I. Kudryashov, J. Gen. Chem. 28, 2448 (1958).*
- [5] N. K. Kochetkov and L. I. Kudryashov, J. Gen. Chem. 27, 248 (1957).*
- [6] N. K. Kochetkov and L. I. Kudryashov, J. Gen. Chem. 28, 1511 (1958).*
- [7] N. K. Kochetkov and L. I. Kudryashov, J. Gen. Chem. 28, 3020 (1958).*

Received March 6, 1958

*Original Russian pagination. See C.B. Translation.

CYCLOSERINE AND RELATED COMPOUNDS

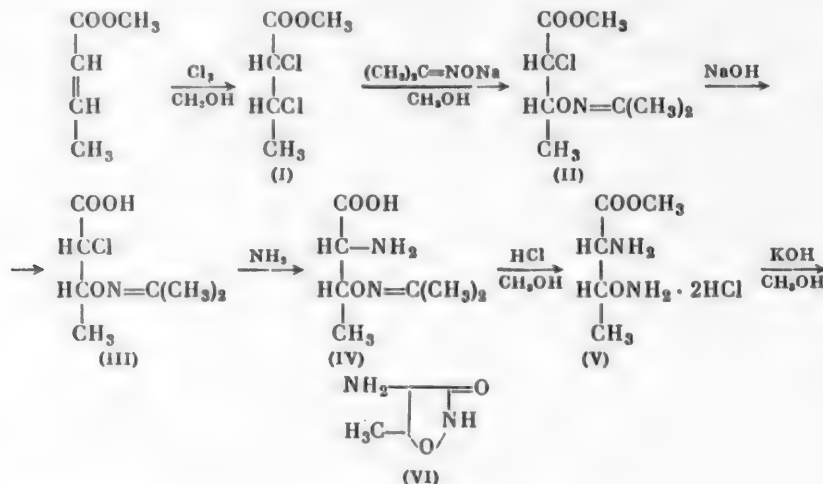
VII. SYNTHESIS OF 5-METHYL-4-AMINOISOXAZOLIDONE-3 (CYCLOTHREONINE)

R. M. Khomutov, M. Ya. Karpeiskii, E. I. Budovskii,
E. S. Severin, and N. K. Kochetkov

We previously developed a method of synthesizing the antibiotic cycloserine, starting from the methyl ester of acrylic acid and acetoxime [1, 2], and showed that the route proposed could be used as a general method of preparing compounds of a new class, isoxazolidones-3.

We recently used this method for the synthesis of 4-N-substituted isoxazolidones-3 [3], which, as was shown in the chemotherapy department of our institute, have a definite biological activity. The present communication is devoted to the synthesis of 5-methyl-4-aminoisoxazolidone-3. The choice of this compound as an object of synthesis was determined both by a wish to establish the applicability of our method to the preparation of 5-substituted homologs of cycloserine and also by the fact that 5-methyl-4-aminoisoxazolidone-3 is genetically connected with the essential amino acid threonine. From the latter fact one might anticipate that 5-methyl-4-aminoisoxazolidone-3 (cyclothreonine) would have a marked biological action. Just as our work was complete, communications [4, 5] appeared on the synthesis of 5-methyl-4-aminoisoxazolidone-3 from threonine through the corresponding hydroxamic acid.

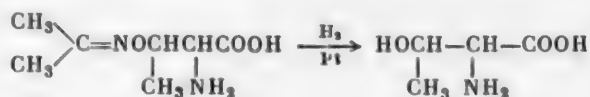
The synthesis of cyclothreonine which we achieved may be represented by the following scheme:



The first stage of the synthesis was the preparation of the methyl ester of α,β -dichlorobutyric acid (I). The methods described in the literature for the preparation of (I) are quite complex and the yields unsatisfactory. We showed that (I) was obtained most conveniently by the chlorination of methyl crotonate in methanol at 10-15°; the reaction proceeded rapidly and the yield of (I) was 70-80%.

Condensation of the dichloroester (I) with the sodio derivative of acetoxime proceeded smoothly under the conditions which we found for the methyl ester of dichloropropionic acid [2], with the difference that heating was necessary to complete the reaction. The yield of the methyl ester of α -chloro- β -isopropylidene-aminohydroxybutyric acid (II) was 35-40%.

In order to prepare α -amino- β -isopropylideneaminohydroxybutyric acid (IV), we hydrolyzed ester (II) into the corresponding acid (III). The latter was subjected to ammonolysis by heating (45-50°) with excess liquid ammonia for 8-10 hours. The yield of the amino acid (IV) reached 50%. To establish the configuration of the amino acid (IV), we made use of the hydrogenation of the grouping $\begin{array}{c} \text{CH}_3 \\ \text{CH}_3 \end{array} \text{C}=\text{N}-\text{O}-$, since it proceeded without touching the asymmetric β -carbon atom.



The procedure we used is a new method of proving the configuration of α -amino- β -isopropylidene-aminohydroxy acids. In all probability this new method will be of wide use and suitable for determining both the structures and the configurations of compounds containing isopropylideneaminohydroxy and aminohydroxy groupings.

As a result of the reaction we isolated (87% yield) and identified D, L-allothreonine, indicating that the amino acid (IV) belonged to the erythro series.

The next stages of the synthesis consisted of the conversion of the amino acid (IV) to the dihydrochloride of methyl α -amino- β -aminohydroxybutyrate (V). As we have shown [2,3], the optimal results in this stage are obtained by treating β -isopropylideneaminohydroxy- α -amino acids with a mixture of methanol and hydrochloric acid with subsequent esterification of the intermediately formed diamino acid, without isolation. In principle, these conditions were found to be suitable for converting the amino acid (IV) into the dihydrochloride (V), which we obtained in 50-60% yield.

The final stage of the synthesis consisted of cyclization of the dihydrochloride (V) into cyclothreonine (VI). The reaction was accomplished by heating (V) with a methanol solution of potassium hydroxide. The cyclothreonine was isolated directly in an analytically pure form at pH 6-5.5 and its yield was 80-85%. Since the cyclization proceeded with retention of the configuration, the cyclothreonine we obtained can be considered to be cis-D,L-5-methyl-4-aminoisoxazolidone-3. The structure of the cyclothreonine was confirmed by IR-spectral data and its homogeneity was established by paper chromatography.

Tests of cyclothreonine in vitro, performed in the chemotherapy department of the institute, showed that the preparation possessed a marked anti-tubercular activity.

EXPERIMENTAL

Methyl α,β -dichlorobutyrate (I). Into a four-necked flask, fitted with a stirrer, a reflux condenser, a gas inlet tube and a thermometer, was placed a solution of 135 g of methyl crotonate in 75 ml of anhydrous methanol and with stirring, a stream of dry chlorine was passed through the reaction mixture at such a rate that the temperature did not exceed + 12°. The chlorination was stopped when the increase in weight reached 100 g (theoretical, 94.5 g). The reaction mixture was poured into water and the lower layer separated and washed with 1% sodium carbonate solution and water. The crude dichloroester was dried over magnesium sulfate and fractionated in vacuum. The yield of pure methyl α,β -dichlorobutyrate was 160-162 g (70%) and the b. p. 78-80° at 21-22 mm.

Methyl α -chloro- β -isopropylideneaminohydroxybutyrate (II). Into a four-necked flask, fitted with a stirrer, a dropping funnel, a thermometer and a reflux condenser, closed with a calcium chloride tube, was placed 70 g of acetoxime and 171 g of methyl α,β -dichlorobutyrate. With vigorous stirring, a solution of the sodio derivative of acetoxime in methanol (from 70 g of acetoxime, 24 g of sodium and 200 ml of methanol) was added to the reaction mixture at such a rate that the temperature did not exceed + 3°. After the addition,

the reaction mixture was stirred for 2 hours at room temperature and for 2-2.5 hours at 55-60°, then acetic acid was added to adjust the pH to 7, the reaction mixture poured into 8-10 times its volume of water and the lower layer separated and extracted with 150 ml of dichloroethane. The combined extracts were washed with water (5 × 200 ml), dried over anhydrous magnesium sulfate, the solvent removed in vacuum and the residue fractionated on a column with an efficiency of 15 theoretical plates to yield a fraction with b. p. 80-82° at 2 mm. The yield of methyl α -chloro- β -isopropylideneaminohydroxybutyrate was 71-72 g (34-35%) and the n_D^{20} 1.4489.

Found %: C 46.44, 46.41; H 6.93, 6.94; N 6.76, 6.75; Cl 17.18, 16.89. $C_8H_{14}O_3NCl$. Calculated %: C 46.37; H 6.74; N 17.07; Cl 17.15.

The colorless, mobile oil was stable to storage; when it was boiled with acids, acetone was liberated and this was identified as the 2,4-dinitrophenylhydrazone with m. p. 124°. A mixture melting point with an authentic sample was not depressed.

α -Amino- β -isopropylideneaminohydroxybutyric acid (IV). 70.0 g of methyl α -chloro- β -isopropylideneaminohydroxybutyrate was emulsified with an equal volume of water and with stirring, a solution of sodium hydroxide (from 14 g of sodium hydroxide and 60 ml of water) was added dropwise at such a rate that the temperature did not exceed +25-28°. The reaction mixture was then made acid to congo by the addition of 50% sulfuric acid at 25-30°. The usual processing yielded 60.3 g (92%) of crude α -chloro- β -isopropylideneamino-hydroxybutyric acid (III).

Without further purification, the acid obtained was placed in a stainless steel autoclave and 250 ml of liquid ammonia and 1 g of ammonium nitrate added. The reaction mixture was heated at 45-50° for 8-10 hours, the ammonia evaporated and the residue dried in vacuum at 100° and recrystallized from aqueous isopropyl alcohol. After three recrystallizations, 28.0-29.0 g (50%) of pure, ammonium chloride-free α -amino- β -isopropylideneaminohydroxybutyric acid with m. p. 210-212° was obtained.

Found %: C 48.48, 48.66; H 8.23, 8.45; N 16.14, 16.28. $C_7H_{14}O_3N_2$. Calculated %: C 48.82; H 8.19; N 16.08.

The colorless crystalline substance was readily soluble in water and insoluble in the usual organic solvents and had R_f 0.72 (mobile phase, n-butanol - acetic acid - water, 4 : 4 : 3, descending, 48 hours and ninhydrin developer).

Hydrogenation of α -amino- β -isopropylideneaminohydroxybutyric acid. 0.9 g of α -amino- β -isopropylideneaminohydroxybutyric acid was dissolved in 50 ml of aqueous ethanol and shaken in an atmosphere of hydrogen in the presence of Pt (from PtO_2). Over a period of 30 hours, 210 ml of hydrogen (21°, 755 mm; 230 ml required) was absorbed. The catalyst was then removed by filtration, the filtrate evaporated to dryness and the residue recrystallized from aqueous alcohol to yield 0.52 g (87%) of D,L-allothreonine with m. p. 251-252° (with decomp.). A mixture with a sample of D,L-threonine melted at 230-234°.

The identity of the substance we obtained with D,L-allothreonine was confirmed by paper chromatography when the R_f was 0.28 (conditions, see previous experiment).

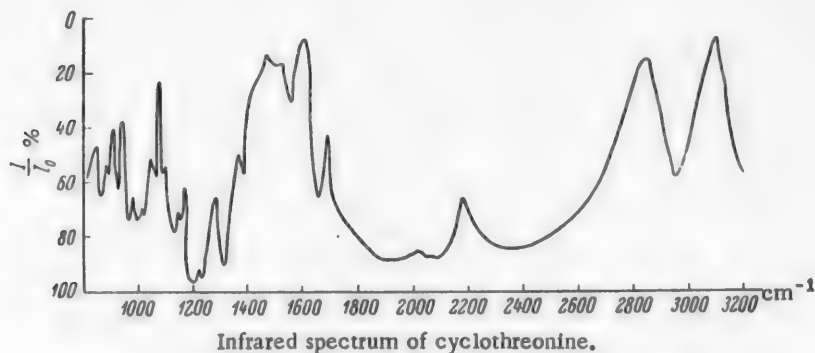
Dihydrochloride of methyl α -amino- β -aminohydroxybutyrate (V). 1.75 g of α -amino- β -isopropylideneaminohydroxybutyric acid was boiled with a mixture of hydrochloric acid and methanol (5 ml of concentrated hydrochloric acid and 8 ml of methanol) for 2-2 $\frac{1}{4}$ hours, while the acetone formed was slowly distilled off. The reaction mixture was then evaporated to dryness in vacuum (bath temperature 50-60°); the solid residue was dissolved in 30 ml of absolute methanol and a fast stream of dry hydrogen chloride passed through for 1 hour with heating; the reaction mixture was boiled for a further 1 hour, decolorized with charcoal and filtered. On the following day the methanol was removed in vacuum and the residue dried in a vacuum desiccator over phosphorus pentoxide and alkali and dissolved in anhydrous isopropyl alcohol with heating. Cooling the solutions to 5-10° deposited an amorphous, hygroscopic precipitate, which was rapidly collected, washed on the filter with dry ether and dried over phosphorus pentoxide at 35-40° and a pressure of 1 mm. The yield of the dihydrochloride of methyl α -amino- β -aminohydroxybutyrate was 1.1-1.2 g (50%) and the m. p. 138-140°.

Found %: C 27.45, 27.23; H 6.41, 6.32; N 12.66, 12.55; Cl 32.47, 32.46. $C_5H_{14}O_3N_2Cl_2$. Calculated %: C 27.13; H 6.38; N 12.61; Cl 32.07.

The white hygroscopic substance was readily soluble in methanol and insoluble in isopropyl alcohol and ether.

D,L-Clis-5-methyl-4-aminoisoxazolidone-3 (VI). 0.45 g of the dihydrochloride of methyl ester of α -amino- β -aminohydroxyalanine was dissolved in the minimal amount of warm methanol, 4.5 ml of 2 N KOH in methanol added and the reaction mixture filtered, boiled for 8-10 minutes on a water bath and decolorized with charcoal. To the reaction mixture was added a 20% solution of acetic acid in absolute isopropyl alcohol to adjust the pH to 5.5-6 and then the substance began to crystallize. To complete crystallization, the reaction mixture was kept at -5 - 10° for 24 hours and the crystalline precipitate then collected, washed with alcohol and ether and dried at 35 - 40° and a pressure of 1 mm. The yield of pure 5-methyl-4-aminoisoxazolidone-3 was 0.18-0.19 g (80%) and the m. p. 156 - 160° (with decomp.).

Found %: C 41.30, 41.18; H 7.28, 7.17. $C_4H_8O_2N_2$. Calculated %: C 41.37; H 6.94.



The colorless crystalline substance was moderately soluble in water and insoluble in the normal organic solvents; it dissolved in acid or alkaline media and formed a silver salt with an aqueous solution of silver nitrate; it gave a cherry color with an aqueous solution of ferric chloride and a characteristic blue color with sodium nitroprusside solution. The homogeneity of the substance was demonstrated by means of paper chromatography, when the R_f was 0.32 (mobile phase, tert.-butanol - n-butanol - 1 N aqueous ammonia, 1 : 1 : 5, ascending, 12 hours, developer, 4% aqueous nitroprusside solution). Infrared spectral data indicate that the substance exists as a dipolar ion (see figure).

SUMMARY

1. 5-Methyl-4-aminoisoxazolidone-3 (cyclothreonine) was synthesized, starting from methyl crotonate and acetoxime.
2. A method is put forward for determining the configurations of α -amino- β -isopropylideneaminohydroxy-carboxylic acids.

LITERATURE CITED

- [1] N. K. Kochetkov, R. M. Khomutov and M. Ya. Karpeiskii, Proc. Acad. Sci. USSR 111, 831 (1956).*
- [2] N. K. Kochetkov, R. M. Khomutov, M. Ya. Karpeiskii, and E. I. Budovskii, J. Gen. Chem. 28, 3013 (1958).*
- [3] R. M. Khomutov, M. Ya. Karpeiskii, E. I. Budovskii, E. S. Severin, and N. K. Kochetkov, J. Gen. Chem. 29, 642 (1959).*
- [4] P. A. Platner, A. Boller, H. Frick, et al., Helv. Chim. Acta 40, 1531 (1957).

*Original Russian pagination. See C.B. Translation.

[5] C. H. Stammer, A. Wilson, C. Spenser, F. Bachelor, F. W. Holly, and K. Folkers, J. Am. Chem. Soc. 79, 3236 (1957).

Received February 10, 1958.

SYNTHESIS OF SOME FORMAZANS, THIOHYDRAZIDES AND THIADIAZOLINES WITH A CARBOHYDRATE RESIDUE

I. Ya. Postovskii and M. I. Ermakova

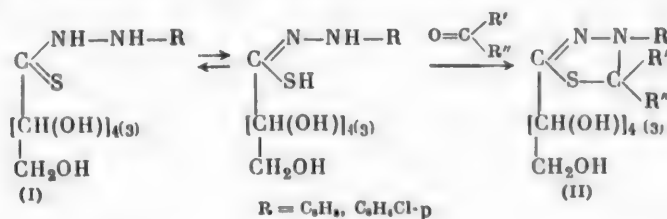
Ural Branch of the Academy of Sciences, USSR

Among heterocyclic compounds with possible physiological activity, compounds in which the heterocycle is connected to a sugar residue by a direct carbon-carbon bond are of great interest.

This type of compound was first synthesized 70 years ago by Griess and Harrow. By condensation with sugars of *o*-phenylenediamine they obtained quinoxaline [1] and benzimidazole compounds [2] with a carbohydrate residue in position 2 of the heterocycle. Heterocyclic compounds with carbohydrate residues again attracted interest only after 50 years had passed and then as a result of investigations on the structure and properties of vitamin B₂ [3, 4]. In recent years, syntheses have been described for quinoxaline [5-7], pyrimidine [8] and benzimidazole [9], compounds with carbohydrate residues. Some of these benzimidazole compounds showed an anticancerous activity [9].

Sulfur-containing heterocycles deserve especial attention among heterocyclic compounds. Therefore, it seemed interesting to us to synthesize and study the properties of some sulfur-containing heterocycles with a carbohydrate residue. Only a few such compounds with carbohydrate residues are described in the literature; for example, descriptions are given of thiophene derivatives [10-12], compounds of 1,3,4-thiadiazole [13] and 1,3,4-thiadiazoline [14-16].

In the present communication we describe the synthesis of some 1,3,4-thiadiazolines with a carbohydrate residue in position 5. We obtained these compounds by treating hydrazides of thioaldonic acids (I) with galactose and arabinose residues with carbonyl containing compounds by the scheme presented,



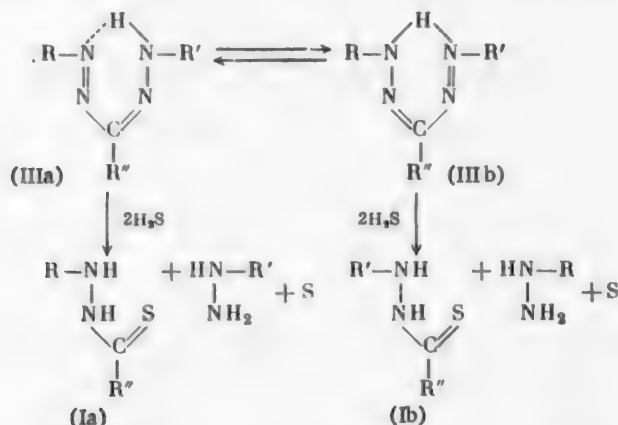
As carbonyl-containing compounds for the synthesis we used formaldehyde, acetone, benzaldehyde, *o*-methoxybenzaldehyde and furfural.*

The thiohydrazides (I), required for the synthesis of thiadiazolines (II), were obtained by Zemplen's method [17] by a hydrogen sulfide reduction of formazyl compounds (III), where R* is a carbohydrate residue.

Formazans can undergo reaction in two tautomeric forms, a and b. In the case where R and R' are

* We attempted to use glucose as the aldehyde so as to obtain a thiadiazoline with two carbohydrate residues. However, in this case we were unable to obtain crystalline products.

different, as a result of the Zemplen reaction one would expect, as follows from the scheme, the formation of four products: two different thiohydrazides and two hydrazines; in the case where $R = R'$, one thiohydrazide and one hydrazine must be obtained. By reduction of compounds (III), (V), (VII) and (IX) (Table 1), where $R = R'$, we obtained hydrazides of thiogalactonic and thioarabonic acids, (X), (XI), (XII) and (XIII) (Table 2).



In the reduction of compounds (IV), (VI) and (VIII), where R and R' were different, contrary to expectation, we also isolated only one thiohydrazide with an unsubstituted aryl and one substituted arylhydrazine. Thus, in the reaction the equilibrium is shifted toward form a, which is of interest in the light of new data on tautomerism of unsymmetrical formazans in relation to the nature of radicals R and R' [18].

The thiohydrazides reacted smoothly with aldehydes in an alcohol medium containing HCl to form 1,3,4-thiadiazolines. The 1,3,4-thiadiazolines we obtained (Table 3) formed colorless, readily crystallizable substances, which were soluble in alcohol, dioxane, and acetone, difficultly soluble in benzene and chloroform and insoluble in water.

We studied some of the reactions and properties of the thiadiazolines obtained. The isomeric thiadiazolines, described by Wyts [14, 15] dissolved in nitric acid with a green color. The thiadiazolines we obtained also gave characteristic green solutions on treatment with oxidants (HNO_3 , $H_2O_2 + H_2SO_4$, $KClO_3 + H_2SO_4$). This color disappeared after some time. Kuhn and Bar [4] found that when quinoxaline compounds with a sugar residue on position 2 were irradiated, this residue was split off, as occurs in the irradiation of vitamin B₂. The thiadiazolines obtained in the present work were irradiated (under the conditions described by Kuhn and Bar), but elimination of the carbohydrate residue was not observed.

Zemplen et al. [17] demonstrated the considerable antitubercular activity of the phenylhydrazide of thiogalactonic acid. The thiohydrazides we synthesized were tested by E. I. Chertkova (Sverdlovsk Tuberculosis Scientific Research Institute) on a virulent strain of tubercle bacilli in the presence and absence of serum. Under these conditions, Zemplen's compound and also the thiohydrazides presented in Table 2 were found to be only weakly active or inactive compounds. In exactly the same way, the 1,3,4-thiadiazolines obtained showed no significant tuberculostatic activity;* the substances showed tuberculostatic activity at concentrations of 1 : 10000 with serum and 1 : 100000 without serum.

EXPERIMENTAL

1. Preparation of formazans

1,5-Diphenyl-3-(D-galacto-pentahydroxyamyl)-formazan (III).** This compound was prepared by the method described by Zemplen and Mester [19] by coupling diazotized aniline with galactose phenylhydrazone (Table 1).

* We would like to take this opportunity to thank E. I. Chertkova for carrying out the tests.

** For nomenclature see [17, 21].

Formazans R-NI NH-R'

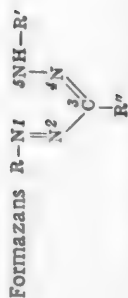
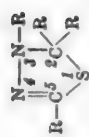
1309

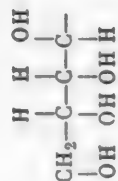
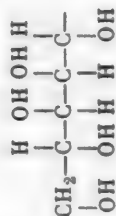
TABLE 2
Thiohydrazides $\begin{array}{c} \text{N-NH-R'} \\ \diagup \quad \diagdown \\ \text{C} \quad \text{SH} \\ | \\ \text{R} \end{array}$

Compound No.	Substituents		Yield (in %)	M. p.	Empirical formula	Nitrogen content (in %)	
	R	R'				found	calculated
(X)	$\begin{array}{c} \text{OH} \quad \text{OH} \quad \text{H} \\ \quad \quad \\ \text{CH}_2-\text{CH}-\text{CH}-\text{CH}-\text{C} \\ \quad \quad \quad \\ \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \end{array}$	C_6H_5	68.2	170–171° (according to [15] 175)	$\text{C}_{12}\text{H}_{18}\text{O}_6\text{N}_2\text{S}$	—	—
(XI)	$\begin{array}{c} \text{OH} \quad \text{OH} \quad \text{H} \\ \quad \quad \\ \text{CH}_2-\text{CH}-\text{CH}-\text{CH}-\text{C} \\ \quad \quad \quad \\ \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \end{array}$	$p\text{-ClC}_6\text{H}_4$	50.4	179–180	$\text{C}_{13}\text{H}_{17}\text{O}_6\text{N}_2\text{ClS}$	8.49	8.32
(XII)	$\begin{array}{c} \text{OH} \quad \text{OH} \quad \text{H} \\ \quad \quad \\ \text{CH}_2-\text{CH}-\text{CH}-\text{CH}-\text{C} \\ \quad \quad \quad \\ \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \end{array}$	C_6H_5	58.3	173–174	$\text{C}_{11}\text{H}_{16}\text{O}_4\text{N}_2\text{S}$	10.19	10.28
(XIII)	$\begin{array}{c} \text{OH} \quad \text{OH} \quad \text{H} \\ \quad \quad \\ \text{CH}_2-\text{CH}-\text{CH}-\text{CH}-\text{C} \\ \quad \quad \quad \\ \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \end{array}$	$p\text{-ClC}_6\text{H}_4$	54.0	177–178	$\text{C}_{11}\text{H}_{15}\text{O}_4\text{N}_2\text{ClS}$	9.23	9.15

TABLE 3
Thiadiazolines



Com- pound No.	Substituents in position					Yield (in %)	M. p.	Empirical formula	Nitrogen content (in %)	
	2	3	4	5	6				found	calculated
(XIV)	H	C ₆ H ₅	C ₆ H ₅			64.2	162–163° [17] 163–164	C ₁₉ H ₂₂ O ₅ N ₃ S	—	—
(XV)	H		C ₆ H ₅			65.8	143–145	C ₁₇ H ₂₀ O ₅ N ₃ S	7.24	7.34
(XVI)	H		C ₆ H ₅			59.5	163–164	C ₂₀ H ₂₄ O ₆ N ₂ S	6.38	6.66
(XVII)	H		C ₆ H ₅			96.2	184–185	C ₁₃ H ₁₈ O ₅ N ₂ S	8.62	8.91
(XVIII)	CH ₃		C ₆ H ₅			73.2	171–172	C ₁₃ H ₂₂ O ₅ N ₂ S	8.28	8.17
(XIX)	H		P-ClC ₆ H ₄			66.1	193–194	C ₁₉ H ₂₁ O ₅ N ₂ ClS	6.66	6.59
(XX)	H		P-ClC ₆ H ₄			67.9	175–176	C ₁₇ H ₁₉ O ₅ N ₂ ClS	6.65	6.74
(XXI)	H		C ₆ H ₅			50.5	178–179	C ₁₃ H ₂₀ O ₄ N ₂ S	7.80	7.77
(XXII)	H		C ₆ H ₅			52.0	154–155	C ₁₈ H ₁₉ O ₅ N ₂ S	8.07	8.00
(XXIII)	H		C ₆ H ₅			76.6	186–187	C ₁₂ H ₁₆ O ₄ N ₂ S	10.09	9.85
(XXIV)	H		P-ClC ₆ H ₄			58.6	193–194	C ₁₃ H ₁₉ O ₄ N ₂ ClS	7.21	7.11
(XXV)	H		P-ClC ₆ H ₄			78.0	177–178	C ₁₆ H ₁₇ O ₅ N ₂ ClS	7.52	7.28



5-Phenyl-1-(p-chlorophenyl)-3-(D-galacto-pentahydroxyamyl)-formazan (IV). 4.2 g of p-chloroaniline in 7.5 ml of concentrated hydrochloric acid and 7.5 ml of water and diazotized with a solution of 3.45 g of sodium nitrite in 10 ml of water at 0°. 8.1 g of galactose phenylhydrazone (m. p. 161-162°) was dissolved in 45 ml of pyridine and 30 ml of water. To the solution of hydrazone, cooled to 0°, was added the solution of diazotized p-chloroaniline after which the reaction mixture was poured into 500 ml of ice water and left overnight. The precipitate was collected, washed with a large amount of water, dried at room temperature and recrystallized from hot butyl alcohol. The yield of formazan was 10.3 g of red platelets with a bronze luster and m. p. 171-172°, which were soluble in alcohol, dioxane, acetone, pyridine, and benzene and slightly soluble in water (for analysis see Table 1).

1,5-di-(p-chlorophenyl)-3-(D-galacto-pentahydroxyamyl)-formazan (V). This compound was obtained similarly to formazan (IV) by coupling diazotized p-chloroaniline with galactose p-chlorophenylhydrazone. The latter was obtained in the following way: 25 g of p-chlorophenylhydrazine hydrochloride was dissolved in 200 ml of water heated to 50-60°. To the solution was added 20.5 g of sodium acetate and 25.2 g of galactose in 20 ml of warm water. After cooling, the hydrazone separated and was collected, dried, and recrystallized from alcohol. The colorless prisms had m. p. 170-171°. The yield was 23.2 g (54.5%).

Found %: N 9.33. $C_{12}H_{17}O_5N_2Cl$. Calculated %: N 9.19.

From 4.2 g of p-chloroaniline and 9.1 g of galactose p-chlorophenylhydrazone, similarly to (IV), we obtained 6.3 g of formazan (V), which appeared as brown platelets with a bronze luster with m. p. 153-154°, which were soluble in the usual organic solvents and sparingly soluble in water.

Found %: C 49.00, 49.11; H 4.77, 4.57. $C_{18}H_{26}O_5N_4Cl_2$. Calculated %: C 48.99; H 4.55. (for nitrogen analysis, see Table 1).

1-Biphenyl-5-phenyl-3-(D-galacto-pentahydroxyamyl)-formazan (VI). This was prepared similarly to (IV). From 3.4 g of p-aminobiphenyl (m. p. 52-54°) and 5.4 g of galactose phenylhydrazone we obtained 5.9 g of formazan, which appeared as brown platelets with a metallic luster with m. p. 158-159°, which were soluble in the usual organic solvents and sparingly soluble in water (for analysis see Table 1).

1,5-Diphenyl-3-(L-arabo-tetrahydroxybutyl)-formazan (VII). This was obtained as described in [20] by coupling diazotized aniline with arabinose phenylhydrazone (Table 1).

5-Phenyl-1-(p-chlorophenyl)-3-(L-arabo-tetrahydroxybutyl)-formazan (VIII). Similarly to (VII), 7.5 g of arabinose, 6.0 g of phenylhydrazine and 7.0 g of p-chloroaniline yielded 13.5 g of formazan in the form of clusters of red needles with m. p. 158-159°, which were soluble in alcohol, benzene, acetone, dioxane, and pyridine and sparingly soluble in ether and water (for analysis see Table 1).

1,5-Di-(p-chlorophenyl)-3-(L-arabo-tetrahydroxybutyl)-formazan (IX). This was obtained similarly to (V) by coupling diazotized p-chloroaniline with arabinose p-chlorophenylhydrazone. The latter was obtained similarly to galactose p-chlorophenylhydrazone. From 6.8 g of p-chlorophenylhydrazine hydrochloride and 5.2 g of arabinose we obtained 4.9 g (50.9%) of arabinose p-chlorophenylhydrazone in the form of colorless needles with m. p. 167-168° (from water).

Found %: N 10.19, 10.32. $C_{11}H_{15}O_4N_2Cl$. Calculated %: N 10.19.

From 2.6 g of p-chloroaniline and 4.9 g of arabinose p-chlorophenylhydrazone, dissolved with heating in 100 ml of water and 40 ml of pyridine, we obtained 3.3 g of formazan in the form of red plates with a bronze luster and with m. p. 165-166°, which were soluble in the usual organic solvents and sparingly soluble in ether and water (for analysis, see Table 1).

2. Preparation of Thiohydrazides

The thiohydrazides of galactonic and arabonic acids were obtained by Zemplen's method [17] by reduction of the corresponding formazans with hydrogen sulfide. The formazan was dissolved in alcohol and treated with hydrogen sulfide 2-3 hours, after which it was left for 48 hours. The solution was then filtered from thiohydrazide, which partially separated in the form of spherical clusters of crystals, and sulfur and the alcohol evaporated in vacuum in a stream of CO_2 . The thiohydrazide obtained after removal of the alcohol was collected and recrystallized from alcohol. (For yields, melting points and analyses see Table 2.)

The thiohydrazides appeared as colorless crystalline substances, which were soluble in alcohol, pyridine, and dioxane and difficultly soluble in benzene, ether, chloroform, dichloroethane, and water.

3. Synthesis of 1,3,4-Thiadiazolines

The 1,3,4-(5-D-galacto-pentahydroxyamyl)- and 1,3,4-(5-L-arabo-tetrahydroxybutyl)-thiadiazolines were obtained by condensation of the appropriate thiohydrazides with aldehydes and ketones in an anhydrous alcohol medium containing 1.5% HCl. The reaction involved heating for 5-20 minutes on a water bath, but in the case of condensation with 40% formaldehyde, the reaction was performed at room temperature for 3-4 hours. The condensation products formed white precipitates, which were collected after the reaction mixture had been cooled, and recrystallized from alcohol.

As an example, we describe the condensation of the phenylthiohydrazone of thioarabonic acid with benzaldehyde (compound XXI, Table 3).

0.3 g of the phenylthiohydrazone of arabonic acid and 0.15 g of freshly distilled benzaldehyde were carefully mixed in 2 ml of anhydrous alcohol containing 1.5% HCl. The mixture was heated on a water bath for 15 minutes. The precipitate which formed after cooling, was collected and recrystallized from alcohol. The 2,3-diphenyl-5-(L-arabo-tetrahydroxybutyl)-1,3,4-thiadiazoline formed colorless needles with m. p. 177-178°, which were soluble in alcohol, dioxane, and acetone and difficultly soluble in water, ether, and benzene. The yield was 0.2 g.

Found %: C 60.22, 60.00; H 5.46, 5.64. $C_{18}H_{20}O_4N_2S$. Calculated %: C 59.99; H 5.56 (for nitrogen analysis see Table 3).

SUMMARY

1. New 1,3,4-thiadiazolines, containing a carbohydrate residue in position 5, were obtained from aryl-thiohydrazides of arabonic and galactonic acids.
2. It was shown that in the preparation of thiohydrazides from formazans with different aryl groups by Zemplen's method, reaction occurred predominantly through one tautomeric form of the formazans.
3. The thiohydrazides and thiadiazolines showed a weak tuberculostatic action.

LITERATURE CITED

- [1] P. Griess and G. Harrow, Ber. 20, 2205 (1887).
- [2] P. Griess and G. Harrow, Ber. 20, 3111 (1887).
- [3] H. Ohle, Ber. 67, 155 (1934).
- [4] R. Kuhn and F. Bar, Ber. 67, 898 (1934).
- [5] G. Henseke and H. Hantschel, Ber. 87, 479 (1954).
- [6] G. Henseke and W. Liebenow, Ber. 87, 1068 (1954).
- [7] G. Henseke and M. Winter, Ber. 89, 956 (1956).
- [8] G. Henseke, Acta Chim. Acad. Scien. Hungaricae 12, 173 (1957).
- [9] D. Heyl, G. Emerson, M. M. Gasser, E. C. Chase, and K. Folkers, J. Am. Chem. Soc. 78, 4491 (1956).
- [10] Yu. A. Zhdanov, L. I. Shcherbakova, and T. N. Egorova, Proc. Acad. Sci. USSR 83, 403 (1952).
- [11] Yu. A. Zhdanov, L. I. Shcherbakova, and R. V. Golovnya, Proc. Acad. Sci. USSR 107, 259 (1956).*
- [12] Yu. A. Zhdanov and G. N. Dorofenko, Proc. Acad. Sci. USSR 113, 601 (1957).*
- [13] J. Sandstrom, C. A. 47, 9271 (1953).
- [14] H. Wüst, Chem. zentr. 1933, II, 2521.

*Original Russian pagination. See C.B. Translation.

- [15] H. Wyts and R. Verstraeten, *Chem. Zentr.* 1935, II, 1546.
- [16] H. Wyts and R. Verstraeten, *C. A.* 30, 7572 (1936).
- [17] G. Zemplen, L. Mester, and A. Messmer, *Ber.* 86, 697 (1953).
- [18] D. Jerchel and W. Woticky, *Lieb. Ann.* 605, 191 (1957).
- [19] G. Zemplen and L. Mester, *Acta Chim. Acad. Scien. Hungaricae* 2, 9 (1952).
- [20] L. Mester and A. Messmer, *J. Am. Chem. Soc.* 78, 1403 (1956).
- [21] G. Zemplen, L. Mester, and E. Eckhart, *Ber.* 86, 472 (1953).

Received March 20, 1958

ALKYLATION OF 4-BROMOPHENOL WITH PROPYLENE AND
 β -AMYLENE IN THE PRESENCE OF $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ AND
 $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ CATALYST

S. V. Zavgorodnii and V. G. Kryuchkova

Voronezh State University

Over a number of years we have made investigations in the field of reactions of halophenols with olefins in the presence of catalysts based on boron trifluoride [1-5]. In the present work a study was made of the alkylation of 4-bromophenol with propylene in the presence of $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ and with β -amylene in the presence of $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ and $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ in a solvent (carbon tetrachloride) and without solvent. It was found that in the presence of $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ and $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$, as with the previously studied pseudobutylene and cyclohexene [4, 5], with propylene and β -amylene, 4-bromophenol gave only ether products. Two compounds were formed with propylene, namely the isopropyl ether of 4-bromophenol (I) and the isopropyl ether of isopropyl-4-bromophenol (II), and one in the reaction with β -amylene, namely the sec-amyl ether of 4-bromophenol (III).

For the alkylation of 4-bromophenol with propylene in the presence of $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ catalyst, the best conditions were molar ratios of reagents and catalyst of 2 : 1 : 0.2, a temperature of 30° and a propylene input rate of 1 liter/hour. Under these conditions (I) and (II) were obtained in yields of 48 and 14% of theoretical, respectively. These products were formed in the same total yield of 62% with molar ratios of 4-bromophenol, propylene and catalyst of 1 : 2 : 0.15, but in this case the reaction was accompanied by considerable tar formation and the yields of (I) and (II) were 37 and 25%, respectively. Raising the reaction temperature to 50° increased the degree of tar formation and strongly lowered the yield of alkylation products. The use of a solvent, carbon tetrachloride, reduced both the degree of tar formation and the yield of (I) and (II). The effect of other reagent and catalyst ratios on the yield of alkylation products is seen from the experimental data in Table 1.

Alkylation of 4-bromophenol with β -amylene in the presence of $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ catalyst in carbon tetrachloride solution at room temperature was accompanied by polymerization and the yield of the sec-amyl ether of 4-bromophenol (III) did not exceed 40% of theoretical. In the presence of $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ in carbon tetrachloride the reaction proceeded more smoothly. The optimal conditions, under which (III) was obtained in a yield of 75% of theoretical, were molar ratios of 4-bromophenol, β -amylene, and $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ of 4 : 1 : 0.2, a temperature of 20-22° and a time of 48 hours. Raising the temperature to 50° and also decreasing the molar ratios of 4-bromophenol to 2 : 1 : 0.2 reduced the yield of (III). In the absence of solvent, intense tar formation was observed. The effect of time and other reagent and catalyst ratios on the yield of (III) is seen from the data in Table 2.

EXPERIMENTAL

The 4-bromophenol required for the reaction was obtained by bromination of phenol [6]; the colorless crystals had m. p. 63°. The propylene was used in the form of a propane-propylene mixture containing 80% propylene, 6% ethylene and 1% isobutylene. The β -amylene was isolated from the still residues from the production of divinyl by S. V. Lebedev's method via the dibromide and fractionation of the amylene fraction on a column with an efficiency of 25-30 theoretical plates. The product had b. p. 35-36°, d_{20}^{20} 0.6576, n_D^{20} 1.4012. The catalyst was prepared as previously [4].

Alkylation of 4-bromophenol with propylene in the presence of $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$. Into a reaction flask was placed anhydrous orthophosphoric acid, which was saturated with boron trifluoride until the gain in weight corresponded to the compound $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ (It was better when the boron trifluoride was in a slight excess). To the catalyst obtained was added crystalline 4-bromophenol and with vigorous stirring, propylene was passed into the the light yellow, sirupy mixture (in reactions without solvent the 4-bromophenol at first partly remained in the crystalline form) at such a rate the reaction temperature did not exceed 30-32°. Intense absorption of propylene began 25-30 minutes from the beginning of its introduction. When the calculated amounts of propylene had been passed in, the reaction mixture, which usually appeared as a clear dark brown liquid, was stirred for 4 hours at the temperature of the experiment, left for a definite time (12-14 hours) at room temperature and then treated with 5% sodium hydroxide solution until the phenol compounds were completely separated from the ethers. When the reaction products were treated with sodium hydroxide solution, the dark brown mixture rapidly changed to a clear, light yellow liquid, which was treated with ether and the ether layer separated, washed with water, dried with calcium chloride and distilled. The most characteristic experiments are presented in Table 1.

TABLE 1

Alkylation of 4-Bromophenol with Propylene in the Presence of $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ at 30-32°

Expt. No.	Molar ratios of bromophenol, propylene and catalyst**	Rate of propylene input (in liters/hour)	Obtained (in % of theoretical)		Residue in distillation flask (in g)
			(I)	(II)	
1	4 : 1 : 0.30	0.7	34.8	8.6	1.65
2	2 : 1 : 0.50	0.5	21.5		
3	2 : 1 : 0.30	1.0	29.9	24.5	1.50
4	2 : 1 : 0.30	1.0	14.9	8.1	1.30
5	2 : 1 : 0.20	1.0	47.6	14.3	1.95
6	2 : 1 : 0.15	1.2	13.2	9.1	3.95
7	1 : 1 : 0.30	0.4	17.1	18.5	2.41
8	1 : 1 : 0.15	1.3	28.8	25.2	2.40
9	0.5 : 1 : 0.15	1.3	36.9	25.1	4.95

* Experiment 6 was performed at 50°.

** The 4-bromophenol used for alkylation was 0.9 mole in experiment 1, 0.4 mole in experiment 3, 5 and 6 and 0.2 mole in the rest. Experiments 2 and 4 were in CCl_4 as solvent; the rest were without solvent.

The unreacted 4-bromophenol was regenerated from the alkaline solution. The characteristics of the ethers are presented below.

The isopropyl ether of 4-bromophenol was a colorless liquid with a pleasant smell. On standing it crystallized as lustrous white plates with m. p. 21-23° (from anhydrous alcohol).

B. p. 74-75° at 2 mm, d_4^{20} 1.3242, n_D^{20} 1.5358, MR_D 50.54; calc. 49.56.

Found %: Br 37.14. $\text{C}_9\text{H}_{11}\text{OBr}$. Calculated %: Br 37.17.

The isopropyl ether of isopropyl-4-bromophenol was a colorless oily liquid.

B. p. 87° at 1 mm, d_4^{20} 1.1924, n_D^{20} 1.5265, MR_D 66.19; calc. 63.42.

Found %: Br 28.97, 29.03. $\text{C}_{12}\text{H}_{17}\text{OBr}$. Calculated %: Br 31.09.

Alkylation of 4-bromophenol with β -amylenes in the presence of $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ and $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$. Into a flask was placed 0.4 mole (0.2 mole in experiments 11 and 12 and 0.1 mole in experiment 13) of 4-bromophenol, dissolved in 80 ml of carbon tetrachloride, and the calculated amount of boron trifluoride ethyl etherate. With continuous stirring, 0.1 mole of β -amylenes, mixed with 20 ml of carbon tetrachloride, was added to the

light brown, homogeneous liquid. The amylene was added at such a rate that the reaction temperature did not rise above 20-22°. The reaction products were treated as in the reaction with propylene. The results of the experiments are presented in Table 2.

During the initial distillation of the ether compounds, the product first distilled as a colorless liquid and toward the end of the distillation as a light yellow liquid, which darkened on standing due to the presence of partial decomposition products. The residue in the flask was a readily solidifying, dark brown tar. In reactions without solvent (experiments 6 and 8), right from the very beginning, the reaction mixture assumed a dark brown color. Before distillation, the ether compounds appeared as a dark, opaque liquid. The same was observed in experiments with $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ catalyst.

TABLE 2

Alkylation of 4-Bromophenol with β -Amylene in the Presence of $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ and $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ at 20-22°*

Expt. No.	Molar ratios of bromophenol, amylene and catalyst**	Reaction time (in hours)	Yield (in %) of sec-amyl ether of 4-bromophenol	Residue in distillation flask (in g)
1	4 : 1 : 0.3	5	47.5	1.95
2	4 : 1 : 0.3	10	65.7	1.58
3	4 : 1 : 0.2	10	57.2	1.21
4	4 : 1 : 0.2	24	51.6	1.83
5	4 : 1 : 0.2	48	74.7	1.25
6	4 : 1 : 0.2	24	31.3	3.35
7	4 : 1 : 0.2	5	69.3	1.77
8	4 : 1 : 0.2	6	43.2	1.83
9	4 : 1 : 0.2	24	39.4	1.75
10	4 : 1 : 0.1	48	33.1	2.10
11	2 : 1 : 0.3	5	37.9	2.12
12	2 : 1 : 0.2	48	64.1	2.02
13	1 : 1 : 0.3	5	24.9	1.91

* Experiment 6 was performed at 30° and experiment 7 at 50°.

** In experiments 8 and 9, $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ catalyst was used, in all the others, $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$. Experiments 6 and 8 were without solvent.

The sec-amyl ether of 4-bromophenol was isolated as the sole product from the alkylation of 4-bromophenol with β -amylene. The stable (on storage in a sealed vessel) colorless liquid had a pleasant smell.

B. p. 90-91° at 2 mm, d_4^{20} 1.2570, n_D^{20} 1.5288, M_R 59.54; calc. 58.80.

Found %: Br 32.70. $\text{C}_{11}\text{H}_{15}\text{OBr}$. Calculated %: Br 32.82.

SUMMARY

A study was made of the alkylation of 4-bromophenol with propylene and β -amylene in the presence $\text{BF}_3 \cdot \text{H}_3\text{PO}_4$ and $\text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2$ catalysts in carbon tetrachloride as solvent.

It was established that the reaction with propylene yielded the isopropyl ether of 4-bromophenol and the isopropyl ether of isopropyl-4-bromophenol. The sec-amyl ether of 4-bromophenol was formed with β -amylene.

LITERATURE CITED

[1] S. V. Zavgorodnii and V. G. Kryuchkova, Trans. Voronezh State University 32, 25 (1953).

[2] S. V. Zavgorodnii and E. M. Faustova, J. Gen. Chem. 23, 1651 (1953).*

*Original Russian pagination. See C.B. Translation.

- [3] S. V. Zavgorodnii, J. Gen. Chem. 22, 1995 (1952).*
- [4] S. V. Zavgorodnii and V. G. Kryuchkova, J. Gen. Chem. 27, 330 (1957).*
- [5] S. V. Zavgorodnii and V. G. Kryuchkova, Trans. Voronezh State University 40, 125 (1956).
- [6] Synth. Org. Preps. 1, 140 (1949).

Received February 5, 1958

*Original Russian pagination. See C.B. Translation.

INVESTIGATIONS IN THE ANTHRAQUINONE SERIES

XXVII. THE HYDROLYSIS OF 1,5- AND 1,8-NITROSULFONIC ACIDS OF ANTHRAQUINONE* (1,5- AND 1,8-NITROHYDROXYANTHRAQUINONES)

V. V. Kozlov

G. V. Plekhanov Institute of the National Economy, Moscow

Having studied the hydrolysis of mono- and disulfonic acids of anthraquinone and established their two-way conversion, with replacement of the sulfonic group by hydrogen or a hydroxy group [1, 2], we undertook a study of the effect of various substituents in the anthraquinone nucleus on the hydrolysis of the sulfonic group. We established that such substituents as SO_3H in positions 5 and 8 of the molecule of anthraquinone-1-sulfonic acid retarded the replacement of the sulfonic group by hydrogen or hydroxyl [3, 4].

TABLE 1

Hydrolysis of 1,5- and 1,8-Nitrosulfonic Acids of Anthraquinone in an Open System. (0.74 g of K salt, 20 ml of H_2SO_4 , 200° and 6 hours, HgSO_4 , 5% of the weight of the salt of anthraquinone nitrosulfonic acid)

Expt. No.	H_2SO_4 (in %)	α -Nitroanthraquinone obtained (in %)
For the 1,5-isomer		
1	50	33.0
2	50	Traces (after 2 hours)
3	50	17.1 (after 12 hours)
4	60	11.2
5	80	9.5
6	80	4.3
7	80	4.7 (230°, 6 hours)
8	80	11.5 (after 12 hours)
9	80	17.2 (230°, 6 hours)
For the 1,8-isomer		
10	50	21.4
11	80	9.3
12	80	2.35
13	80	5.2 (230°, 6 hours)
14	80	18.6 (230°, 6 hours)

Note. Experiment 1-5, 9-11 and 14, in the presence of mercury, the rest without mercury.

In the present work we studied the effect of the nitro group on the hydrolysis of sulfonic groups in anthraquinone on the example of anthraquinone nitrosulfonic acids. There is no information in the literature on the hydrolysis of these compounds apart from a patent report [5] on the possibility of hydrolyzing 1-nitroanthraquinone-8-sulfonic acid in 50% sulfuric acid at 190-200° with mercury, with the formation of α -nitroanthraquinone.

Our experiments on the heating of sodium salts of 1,5- and 1,8-nitrosulfonic acids of anthraquinone in an open system showed that the hydrolysis of these compounds proceeded with much more difficulty than for the unsubstituted α -sulfonic acid of anthraquinone.

Replacement of the sulfonic group by hydrogen with the formation of α -nitroanthraquinone (melting point of of sublimate 232°) in the absence of mercury salts was only possible at 200° in 80% sulfuric acid over a period of 6 hours in yields of 4.3% of theoretical for the 1,5-isomer and 2.35% for the 1,8-isomer. The hydrolysis conditions could be made somewhat milder by the use of mercury salts, with which the reaction proceeded at 200° to give higher yields in even 50% sulfuric acid: 33% of theoretical for the 1,5-isomer and 21.4% for the 1,8-isomer.

The experiments (Table 1) showed that the hydrolysis of nitroanthraquinonesulfonic acids with the formation

* For communication XXVI, see J. Gen. Chem 26, 2617 (1956).

of nitroanthraquinone was accompanied by side conversions, connected with changes in the nitro group.

As is known [6], heating α -nitroanthraquinone with concentrated sulfuric acid yields an orange solution, from which a red-violet material is precipitated by dilution with water. A similar phenomenon occurred when nitroanthraquinonesulfonic acids were heated with sulfuric acid, only instead of a precipitate, a crimson red solution was formed on dilution with water.

TABLE 2

Hydrolysis of 1,5- and 1,8-Nitrosulfonic Acids of Anthraquinone in Water in Relation to Temperature (0.66 g of substance, 20 ml of water and 6 hours)

Expt. No.	Temperature	Nitro-hydroxy-anthra-quinone obtained (in %)	Unchanged nitro-sulfonic acid (in %)	Amount of tar (in %)
For 1,5-Isomer				
1	230°	6.2	92.8	1.0
2	260	13.0	85.9	1.1
3	290	48.0	49.0	2.5
For 1,8-Isomer				
4	230°	4.14	95.7	
5	260	8.8	90.1	1.02
6	290	30.2	67.5	1.8

Considering these phenomena, we carried out experiments on the hydrolysis of nitroanthraquinonesulfonic acids in water and dilute sulfuric acid in a closed system. The hydrolysis was accomplished in sealed tubes with 0.002 mole of substance which corresponds to 0.666 g of the free nitrosulfonic acid or 0.74 g of its K-salt. The amount of water for the hydrolysis was from 203 to 555 moles per mole of nitroanthraquinonesulfonic acid.

It was established that in a sealed system, hydrolysis of nitroanthraquinonesulfonic acids and their salts in water or dilute sulfuric acid (0.25-10%) at high temperatures (230-290°) proceeded only with replacements of the sulfonic group by hydroxyl by the scheme

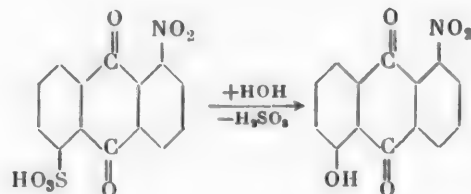
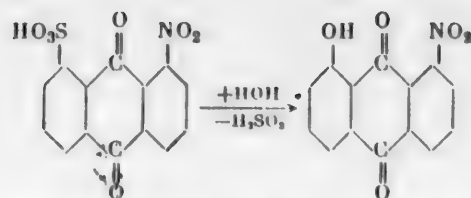


TABLE 3

Hydrolysis of 1,5- and 1,8-Nitrosulfonic Acids of Anthraquinone in Water in Relation to Time (0.66 g of substance and 20 ml of water)

Expt. No.	Time (in hrs)	Nitro-hydroxy-anthra-quinone obtained (in %)	Unchanged nitro-sulfonic acid (in %)	Amount of tar (in %)
For the 1,5-Isomer at 230°				
1	6	6.2	93.8	
2	12	9.25	90.75	
The same at 260°				
3	3	9.25	89.75	1.0
4	6	13.0	85.9	1.1
5	12	20.0	76.5	3.5
For the 1,8-Isomer at 230°				
6	6	4.14	95.7	
7	12	6.35	93.3	
The same at 290°				
8	3	3.75	95.27	0.98
9	6	8.8	90.1	1.02
10	12	12.8	85.4	1.8

* As in original - Publisher.



The hydrolysis of nitroanthraquinonesulfonic acids depended primarily on temperature (see Table 2). Below 230° hydrolysis did not occur. The yield of hydrolysis products increased with an increase in the heating time (see Table 3). In the hydrolysis of the 1,5-nitrosulfonic acid of anthraquinone at 230°, after 6 hours the yield of 1,5-nitroanthraquinone was 6.2% of theoretical and after 13 hours, 9.3%. In the hydrolysis of the 1,8-nitrosulfonic acid of anthraquinone in water at 260°, after 3 hours the yield of 1,8-nitroanthraquinone was 3.72% and after 6 hours, 8.4%.

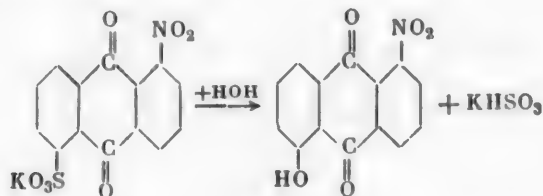
TABLE 4

Hydrolysis of the 1,8-Nitrosulfonic Acid of Anthraquinone in Relation of Volume of Water (0.66 g of substance, 0.55-1.65 mole of water, 290° and 6 hours)

Expt. No.	Amount of water (in ml)	Nitrohydroxyanthraquinone obtained (in %)	Unchanged nitrosulfonic acid (in %)	Amount of tar (in %)
1	10	27.6	71.0	1.00
2	20	30.2	67.5	1.02
3	30	60.5	38.5	0.9

An essential factor, affecting the hydrolysis, was the amount of water per mole of starting material (see Table 4).

Salts of nitroanthraquinonesulfonic acids were hydrolyzed with more difficulty than the free acids, which is in complete agreement with the behavior of sulfonic groups in mono- and disulfonic acids of anthraquinone. While the free 1,5-nitrosulfonic acid of anthraquinone was 48% hydrolyzed in water at 290° over a period of 6 hours, under the same conditions the K-salt of this acid formed only 6.2% of nitrohydroxyanthraquinone. The bisulfite formed during the hydrolysis retarded the replacement of the sulfonic group by hydroxyl.



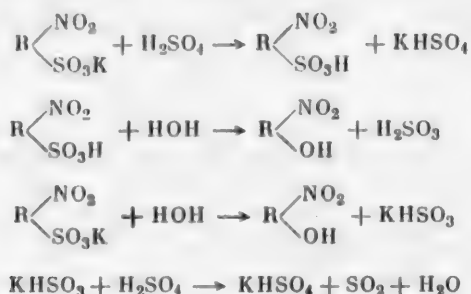
A definite pH was required for hydrolysis and this was achieved by the addition of sulfuric acid. Thus, if the K-salt of the 1,5-nitrosulfonic acid of anthraquinone was heated at 290° for 6 hours, not with water but

TABLE 5

Hydrolysis of K-salts of 1,5- and 1,8-Nitrosulfonic Acids of Anthraquinone in Water and Dilute Sulfuric Acid (0.74 of substance, 20 ml of H₂SO₄, 290° and 6 hours)

Expt. No.	H ₂ SO ₄ (in %)	Nitrohydroxyanthraquinone obtained (in %)	Unchanged nitrosulfonic acid (in %)	Amount of tar (in %)
For the 1,5-nitrosulfonic acid of anthraquinone				
1	Water	6.2	92.8	1.0
2	0.25	35.1	63.4	1.5
3	5.0	41.8	55.2	3.0
4	10.0	42.6	47.4	10.1
For the 1,8-nitrosulfonic acid of anthraquinone				
5	Water	3.73	95.42	0.85
6	0.25	22.4	76.35	1.25
7	5.0	24.5	73.0	2.5
8	10.0	27.0	63.2	9.8

with 10% sulfuric acid, the nitrohydroxyanthraquinone was obtained in almost the same yield as with the free nitrosulfonic acid, i.e., 42% of theoretical (see Table 5).



Increasing the sulfuric acid concentration from 10 to 50% lowered the nitrohydroxyanthraquinone yield to zero. Hydrolysis of the 1,5- or 1,8-nitrosulfonic acids with 50-80% sulfuric acid again led to the appearance of hydrolysis products, whose amount increased with the increase in the sulfuric acid concentration. Dilution of the sulfuric acid solution with water produced a deep crimson color, similar to that noted in hydrolysis experiments in an open system.

However, in these cases the hydrolysis products were not homogeneous. They were insoluble in water, but soluble in many organic solvents, from which they crystallized as red needles. The hydrolysis products dissolved in sulfuric acid giving a yellow-orange color, in caustic alkalis with a pale violet color and partially dissolved in sodium carbonate solution with a violet color. The products also sublimed readily as red needles. Despite the crystalline form in which the hydrolysis products could be obtained after crystallization from a solvent or sublimation, they had low, indefinite melting points and were not discrete substances.

By using the partial solubility of the hydrolysis products in sodium carbonate solution and fractional crystallization from acetic acid and alcohol it was possible to isolate small amounts of individual substances, which indicated that the hydrolysis of the 1,5- and 1,8-nitrosulfonic acids of anthraquinone in concentrated sulfuric acid in a closed system under pressure was a complex process. Among the reaction products were found α -nitroanthraquinone (m. p. 230°), anthraquinone (m. p. 281°), α -hydroxyanthraquinone (m. p. 187°) and products of unestablished structure.

The formation of these substances was the result of hydrolysis of the sulfonic and nitro groups of the original nitrosulfonic acids of anthraquinone. The formation of nitrogen-containing products of unestablished structure was the result of the oxidizing action of sulfuric acid and oxides of nitrogen under the drastic hydrolysis conditions. We noted similar oxidation phenomena under drastic hydrolysis conditions for the 1,5-disulfonic acid of anthraquinone [4].

We established that nitroanthraquinone was capable of giving quite stable adducts with hydroxyanthraquinones.

Addition of 5% mercuric sulfate in experiments in which the 1,5- and 1,8-nitrosulfonic acids of anthraquinone were heated with water and dilute sulfuric acid in a closed system prevented hydrolysis and the starting material was recovered unchanged. The addition of mercuric sulfate in experiments in which the same isomeric nitrosulfonic acids of anthraquinone were heated in 80% sulfuric acid in a closed system tripled the amount of hydrolysis products, but did not lead to a discrete substance either.

In experiments both in open and in sealed systems, the hydrolytic elimination of sulfonic groups from the 1,5-nitrosulfonic acid of anthraquinone proceeded more readily than with the 1,8-isomer.

A comparison of the hydrolysis of the α, α' -nitrosulfonic acid of anthraquinone with the hydrolysis of the α -sulfonic acid [1, 2] and the α, α' -disulfonic acid of anthraquinone [3, 4] shows that the NO_2 group, by changing the inductive and tautomeric effect of the carbonyl group, strongly lowers the lability of the α -sulfonic group.

EXPERIMENTAL

(With the participation of N. B. Filippova and V. G. Smirnova)

Starting materials. The 1,5- and 1,8-nitrosulfonic acids of anthraquinone were obtained in the form of the K-salts by nitration of the technical K-salt of the α -sulfonic acid of anthraquinone in sulfuric acid [7]. The sharpest separation of the isomeric nitrosulfonic acids was achieved with 4.27% of water in the nitrating mixture or 3.6% in the reaction mass.

The K-salt of the 1,5-nitrosulfonic acid of anthraquinone (rhombs) reacted with chlorate in hydrochloric acid [8] to form nitrochloroanthraquinone with m. p. 314° (needles from acetic acid).

The K-salt of the 1,8-nitrosulfonic acid of anthraquinone formed needles; the nitrochloroanthraquinone formed needles with m. p. 263° (from acetic acid).

The free 1,5- and 1,8-nitrosulfonic acids of anthraquinone were obtained by decomposition of the barium salts with sulfuric acid.

Processing of the hydrolyzate. Hydrolysis in an open system was carried out in a round-bottomed flask with air condensers with heating on an oil bath. The cooled hydrolyzate was poured into 100 ml of cold water and the precipitate filtered off and washed with boiling water until the filtrate became colorless. The precipitate was dried in a desiccator, weighed, its melting point determined and the precipitate recrystallized or sublimed.

In hydrolysis in tubes in water or dilute sulfuric acid, the precipitate present in the hydrolyzate was collected on a vacuum funnel, washed with water until the wash waters gave a neutral reaction to congo and dried at 100°.

In hydrolysis in 50-80% sulfuric acid, the tube contents were poured into 500 ml of water. The precipitate formed was collected and treated as above.

The dried product from hydrolysis in water or dilute sulfuric acid was weighed and the melting point determined.

The products from hydrolysis at 260-290° were contaminated with tar. In these cases, the crude product was dissolved in an aqueous sodium carbonate solution, filtered free from impurities and the purified product isolated from the filtrate by acidification with hydrochloric acid.

The hydrolysis products from both isomeric nitrosulfonic acids contained nitrogen but not sulfur.

When heated with sodium sulfide in an alkaline medium, the products were reduced and then they were able to form diazo compounds which coupled readily with resorcinol or P-salt.

The 1,5-nitrohydroxyanthraquinone, formed by hydrolysis of the 1,5-nitrosulfonic acid of anthraquinone, has not been described in the literature and was insoluble in water, but soluble in organic solvents. The substance dissolved in caustic alkalis and carbonates with a violet-blue color, in acetic acid with a cherry red color and in concentrated sulfuric acid with a red color. It crystallized from acetic acid as dark red needles and from alcohol as yellow needles with m. p. 268° (in a sealed capillary).

Found %: C 62.68, 62.73; H 2.82, 2.61; N 5.09, 5.28. $C_{14}H_7O_5N$. Calculated %: C 62.3; H 2.6; N 5.2.

1,8-Nitrohydroxyanthraquinone, formed by hydrolysis of the 1,8-nitrosulfonic acid of anthraquinone, has not been described in the literature and was similar in solubility to the 1,5-isomer. It dissolved in caustic alkali with a violet-red color, in sodium carbonate with a cherry red color, in acetic acid with an orange-red color and in an alcohol with an orange color. From both solvents the substance crystallized as red needles with m. p. 253° (in a sealed capillary).

Both 1,5- and 1,8-nitrohydroxyanthraquinone sublimed readily as long red needles.

Found %: C 62.47, 62.27; H 2.7, 2.6; N 4.99, 5.11. $C_{14}H_7O_5N$. Calculated %: C 62.3; H 2.6; N 5.2.

The mother solution, separated from the precipitate and combined with the wash waters, did not contain NO_2^- or NO_3^- ions, indicating that the nitro group was not eliminated from the nitrosulfonic acid during hydrolysis. The smell of SO_2 , detected when the tubes were opened, indicated that the sulfonic group was eliminated in the form of sulfurous acid.

The mother solution was extracted with benzene to remove traces of hydrolysis products and was then subjected to oxidative chlorination with potassium chlorate. The unchanged starting material was characterized by the melting point of the nitrochloroanthraquinone, the amount of which was calculated on the nitrosulfonic acid of anthraquinone or the K-salt.

SUMMARY

1. The hydrolysis of 1,5- and 1,8-nitrosulfonic acids of anthraquinone was possible in sulfuric acid and water without mercury salts both in an open and a closed system at high temperature.
 2. Hydrolysis in water in sealed tubes led to the formation of products from the replacement of the sulfonic group by hydroxyl, namely 1,5- and 1,8-nitrohydroxyanthraquinones, which were obtained for the first time.
 3. Hydrolysis in concentrated sulfuric acid in an open system yielded products of replacement of the sulfonic group by hydrogen, namely, α -nitroanthraquinone. Hydrolysis in sealed tubes led to the formation of a complex mixture of products of replacement of both the sulfonic and the nitro group by hydrogen and hydroxyl.
- In both systems, hydrolysis by concentrated sulfuric acid was complicated by oxidative conversions.
4. The presence of a nitro group in position 5 and especially 8 of anthraquinone-1-sulfonic acid strongly lowered the lability of the sulfonic group in comparison with the behavior of the latter in the 1-sulfonic acid or the 1,5- and 1,8-disulfonic acids of anthraquinone.

LITERATURE CITED

- [1] V. V. Kozlov and A. A. Egorova, J. Gen. Chem. 25, 809 (1955).*
- [2] V. V. Kozlov and A. A. Egorova, J. Gen. Chem. 25, 1997 (1955).*
- [3] V. V. Kozlov, J. Gen. Chem. 25, 1206 (1955).*
- [4] V. V. Kozlov, J. Gen. Chem. 26, 2617 (1956).*
- [5] German Pat. 160,104; Friedl., 8, 236; Chem Zentr. 1905, I, 1447.
- [6] N. N. Vorozhtsov, Stages in the Synthesis of Dyes., Sci. Chem. Tech. Press, 220 (1926).**
- [7] German Pat. 164,293; Friedl. 8, 232, 235.
- [8] German Pat. 214,150; Chem. Zentr. 1909, II, 1394.

Received February 8, 1958.

* Original Russian pagination. See C.B. Translation.

** In Russian.

INTERACTION OF 6-CHLOROMETHYLQUINOLINE WITH AMINES

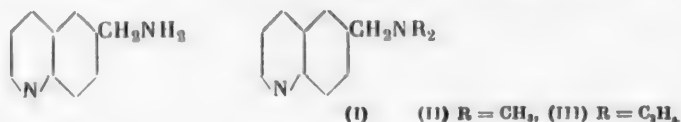
B. P. Lugovkin

All-Union Labor Protection Scientific Research Institute,
All-Union Central Council of Trade Unions, Kazan

In previous reports [1, 2] it was shown that the halogen atoms in 6-chloro- and bromomethylquinolines could be exchanged for an iodine atom or alkoxy, cyano or phosphonium groups.

In the present article we present the results of an investigation of the reaction of 6-chloromethylquinoline with ammonia, secondary aliphatic amines, aniline and secondary heterocyclic amines.

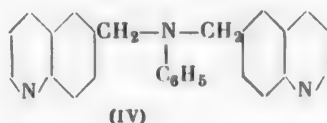
The interaction of the chloride with a concentrated aqueous solution of ammonia at normal temperature yielded 6-(aminomethyl)-quinoline (I) as a colorless, oily liquid in 46% liquid.



Heating 6-chloromethylquinoline with aqueous solutions of dimethyl- and diethylamine yielded 6-(dimethylaminomethyl)-quinoline (II) and 6-(diethylaminomethyl)-quinoline (III), which appeared as colorless, oily liquids (yields 42 and 64%, respectively).

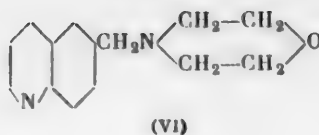
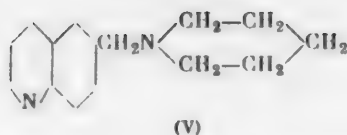
In ether solution with hydrogen chloride, 6-(aminomethyl)-quinoline gave a monohydrochloride, while the 6-(dialkylaminomethyl)-quinolines gave dihydrochlorides. Evidently, in amine (I) the nitrogen atom in the ring has a greater basicity than that in the NH₂ group. Amines (II) and (III) added 2 molecules of methyl iodide to form crystalline dimethiodides.

When the chloride (2 moles) was reacted with aniline by heating the components in alcohol solution, it was possible to isolate bis-(quinolyl-6-methyl)-aniline (IV) in the form of white crystals in 38% yield. This substance gave a dimethiodide with methyl iodide.



Heating 6-chloromethylquinoline with an aqueous solution of piperidine gave 6-(N-piperidylmethyl)-quinoline (V), which formed a thick colorless oily liquid with a weak piperidine smell (yield 69%). Under the same conditions, the reaction with morpholine yielded 6-(N-morpholylmethyl)-quinoline (VI) in a crystalline form (yield 47%). Both amines formed dihydrochlorides and dimethiodides.

The interaction of 6-chloromethylquinoline with amines was accompanied by the formation of tarry products. The amines synthesized were sensitive to atmospheric oxygen and became colored on storage, even in the dark.



EXPERIMENTAL

6-(Aminomethyl)-quinoline. To 3.5 g of 6-chloromethylquinoline was added 250 ml of ammonia (24%). The solution was kept for 48 hours with periodic shaking, filtered free from a slight precipitate, saturated with solid potassium carbonate and heated slightly on a water bath to remove ammonia. The oily, yellowish liquid liberated was separated and the solution extracted with chloroform. After drying with baked potassium carbonate and removal of the solvent, the residue was repeatedly vacuum distilled. We obtained 1.44 g of amine.

The substance dissolved in water, alcohol and chloroform and with more difficulty in ether.

B. p. 158-159° at 2 mm, n_D^{20} 1.6390, d_4^{20} 1.0220.

Found %: N 17.36. $C_{10}H_{10}N_2$. Calculated %: N 17.72.

The monohydrochloride of 6-(aminomethyl)-quinoline was obtained by passing hydrogen chloride into a solution of the amine in dry ethyl ether. The white crystals with m. p. 239° (from anhydrous alcohol) were readily soluble in water and difficultly so in alcohol.

Found %: Cl 17.86. $C_{10}H_{10}N_2 \cdot HCl$. Calculated %: Cl 18.22. $C_{10}H_{10}N_2 \cdot 2HCl$. Calculated %: Cl 30.69.

The diacetyl derivative of the amine was obtained by the action of acetic anhydride (1 mole). The reaction proceeded with the evolution of heat and at the end, the mixture was heated on a boiling water bath for 10 minutes. The colorless crystals with m. p. 105° (from toluene) readily dissolved in water, alcohol, and chloroform, with more difficulty in toluene and were insoluble in ether. Standing for several days with methyl iodide in methanol solution gave the methiodide. The yellow crystals had m. p. 112-113° (from alcohol).

Found %: I 33.21. $C_{16}H_{17}O_2N_2I$. Calculated %: I 33.04.

6-(Dimethylaminomethyl)-quinoline. A mixture of 2.5 g of the chloride and 15 ml of an aqueous solution of dimethylamine (d_4^{20} 0.951) was heated on a water bath at 55-60° for 40 minutes; the chloride dissolved rapidly. The solution was saturated with solid potassium carbonate and then extracted with chloroform. After drying with fused potassium carbonate and removal of the solvent, the residual dark brown liquid was vacuum distilled. We obtained 1.1 g of amine. The substance dissolved in water and the usual organic solvents.

B. p. 143-144° at 1 mm, n_D^{20} 1.5762, d_4^{20} 1.0074.

Found %: N 14.87. $C_{12}H_{14}N_2$. Calculated %: N 15.05.

The dihydrochloride was obtained by passing hydrogen chloride into a solution of the amine in dry ethyl ether. The white crystals with m. p. 242-243° (from anhydrous alcohol) dissolved readily in water and with difficulty in alcohol.

Found %: Cl 27.18. $C_{12}H_{14}N_2Cl_2$. Calculated %: Cl 27.37.

To 0.3 g of amine in 3 ml of dry ether was added 0.4 ml of methyl iodide. Keeping the mixture for 24 hours yielded yellow crystals of the dimethiodide (yield 93%). The m. p. was 232° (after washing with hot alcohol). The substance dissolved readily in water, with great difficulty in hot alcohol and was insoluble in ether.

Found %: I 53.69. $C_{14}H_{16}ON_2I_2$. Calculated %: I 54.01.

6-(Diethylaminomethyl)-quinoline. A mixture of 3.05 g of chloride and 5 g of diethylamine in 15 ml of water was heated on a water bath at 55-60° for 40 minutes with stirring. Appropriate processing (similar to the experiment with dimethylamine) yielded 2.35 g of amine. The substance dissolved in the usual organic solvents, but not in water.

B. p. 160-161° at 2 mm, n_D^{20} 1.5658, d_{20}^{20} 1.0024.

Found %: N 13.22. $C_{14}H_{18}N_2$. Calculated %: N 13.08.

The dihydrochloride formed white crystals with m. p. 241-242° (from anhydrous alcohol), which dissolved readily in water and with difficulty in alcohol.

Found %: Cl 24.61. $C_{14}H_{20}N_2Cl_2$. Calculated %: Cl 24.70.

The dimethiodide formed yellow crystals. The yield was 78% and the m. p. 216-217° (from alcohol). The substance dissolved in water and hot alcohol but not in ether.

Found %: I 50.70. $C_{16}H_{24}N_2I_2$. Calculated %: I 50.97.

Bis-(quinolyl-6-methyl)-aniline. Experiment 1. 4 g (2 mole) of chloride in 15 ml of alcohol and 1.04 g of freshly distilled aniline were heated together on a water bath at 70-75° for 1 hour. The solution was diluted with 30 ml of water, saturated with solid potassium carbonate and the liberated alcohol layer separated. Removal of the solvent yielded a thick dark brown liquid, which partially crystallized on standing. Extraction with benzene and boiling the solution twice with charcoal yielded 1.6 g of yellowish crystals. After recrystallization from toluene, the substance formed white needles with m. p. 141°.

The product dissolved in alcohol, chloroform, and benzene, with difficulty in ether, and was insoluble in water.

Found %: N 11.01. $C_{26}H_{21}N_3$. Calculated %: N 11.20.

The dimethiodide was obtained by keeping the reagents in acetone solution for 3 days. The yield was 98%. The dark yellow crystals had m. p. 197° (from alcohol). The product dissolved in water and hot alcohol and with great difficulty in acetone.

Found %: I 38.26. $C_{28}H_{27}N_3I_2$. Calculated %: I 38.51.

Experiment II. To 3 g (1 mole) of chloride in 30 ml of alcohol was added 1.6 g of aniline. Keeping the solution for 2 days and then processing it (similarly to experiment I) gave a thick, brown, uncrystallizable liquid from which it was not possible to isolate 6-(anilinomethyl)-quinoline by distillation in a vacuum of 1 mm.

6-(N-Piperidylmethyl)-quinoline. A mixture of 2.5 g of chloride and 2.5 g of piperidine, dissolved in 15 ml of water, was heated on a water bath at 60-65° for 40 minutes with stirring. Appropriate processing (analogously to the experiments with dialkylamines) yielded 2.2 g of amine.

The product dissolved in the usual organic solvents and with difficulty in hot water.

B. p. 190-191° at 1.5 mm, n_D^{20} 1.5950, d_{20}^{20} 1.0100.

Found %: N 12.14. $C_{15}H_{18}N_2$. Calculated %: N 12.38.

The dihydrochloride formed slightly yellowish, hygroscopic crystals with m. p. 232° (from anhydrous alcohol, with charcoal). It was precipitated from alcohol solution by dry ether in the form of an oily liquid. It dissolved readily in water and hot alcohol.

Found %: Cl 24.09. $C_{15}H_{22}N_2Cl_2$. Calculated %: Cl 23.71.

The dimethiodide was obtained analogously to (II and III). It formed yellow crystals. The yield was 80% and the m. p. 216° (from glacial acetic acid). The substance dissolved readily in water and with difficulty in alcohol and glacial acetic acid; it was insoluble in ether.

Found %: I 49.92. $C_{17}H_{24}N_2I_2$. Calculated %: I 49.77.

6-(N-Morpholylmethyl)-quinoline. A mixture of 2.5 g of chloride and 2.5 g of morpholine, dissolved in 15 ml of water, was heated on a water bath at 60-65° for 40 minutes with stirring. The reaction product, which formed a thick, dark brown liquid, was vacuum distilled.* The b. p. was 192-193° at 1 mm. The

* The vacuum distillation was performed using a small amount of glass wool and a capillary to prevent carry-over from the flask.

weight was 1.5 g. The very thick liquid crystallized completely on standing (crystallization was rapid on seeding). The colorless crystals had m. p. 66°. They dissolved readily in water and the usual organic solvent and also in light benzene.

Found %: N 11.95. $C_{14}H_{16}ON_2$. Calculated %: N 12.28.

The dihydrochloride formed white crystals with m. p. 242° (after washing with hot alcohol), which dissolved readily in water and with great difficulty in alcohol.

Found %: Cl 23.11. $C_{14}H_{18}ON_2Cl_2$. Calculated %: N 23.55.

The dimethiodide was obtained by heating the amine and methyl iodide on a water bath at 75-85° for 30 minutes (reaction in ether solution at room temperature proceeded slowly). The dark yellow crystals had m. p. 215-216° (after washing with hot alcohol). The yield was 46%. The product dissolved readily in water, with great difficulty in hot alcohol and was insoluble in ether.

Found %: I 49.76. $C_{16}H_{22}ON_2I_2$. Calculated %: I 49.57.

SUMMARY

A study was made of the reaction of 6-chloromethylquinoline with ammonia, dimethyl-, and diethylamines, aniline, piperidine, and morpholine. Amino derivatives of 6-methylquinoline were synthesized.

LITERATURE CITED

- [1] B. P. Lugovkin, J. Gen. Chem. 26, 1733 (1956).*
- [2] B. P. Lugovkin, J. Gen. Chem. 27, 529 (1957).*

Received February 24, 1958

*Original Russian pagination. See C.B. Translation.

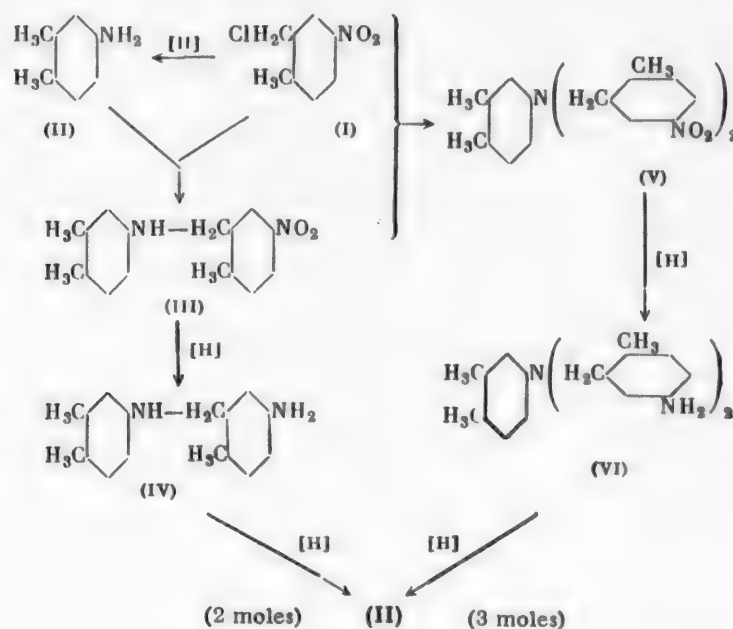
CATALYTIC REDUCTION OF HALOALKYL-SUBSTITUTED AROMATIC NITRO COMPOUNDS

V. M. Berezovskii and Yu. P. Sobolev

All-Union Vitamin Research Institute

The reduction of haloalkyl-substituted aromatic nitro compounds and the elimination of the halogen proceed in high yield in the presence of a catalyst selected from the noble metals in an acidic medium, as shown by the example of 2-chloromethyl-4-nitrotoluene [1]. The use of the Raney nickel catalyst led to low yields of the aromatic amine and it was possible to obtain better results only under certain conditions (at rather low concentration of the substance in an alcoholic alkali solution) [2].

We showed in the present work that the cause of the low yields of o-4-xylylidine (II), formed in the hydrogenation of 2-chloromethyl-4-nitrotoluene (I) over Raney nickel is the secondary reaction of alkylation of the aromatic amine by the as yet unreduced haloalkyl aromatic nitro compound. The secondary amine (III), formed thereby, suffers a further hydrogenation to 2'-methyl-5'-aminobenzyl-N-o-xylylidine (IV) which was isolated by us from the reaction products. The structure of diamine (IV) was proved by analysis for the primary amino group, by cleavage during hydrogenolysis into two moles of o-4-xylylidine and by the synthesis from o-4-xylylidine and 2-chloromethyl-4-nitrotoluene through the intermediate formation of the secondary amine (III).



The reaction of catalytic hydrogenation of 2-chloromethyl-4-nitrotoluene is evidently complicated by the formation of triamine (VI) as a result of alkylation of secondary amine (III) by 2-chloromethyl-4-nitrotoluene to give tertiary amine (V) was readily prepared by us by alkylation of ether secondary amine (III) (in

toluene to give tertiary amine (V) which suffers a further hydrogenation into compound (VI.) Triamine (VI) was readily prepared by us by alkylation of either secondary amine (III) (in the presence of sodium bicarbonate) or o-4-xylydine directly (in neutral medium) by 2-chloromethyl-4-nitrotoluene. Dialkylation takes place in the latter instance owing to the fact that the hydrogen halide is removed from the reaction zone in the form of o-4-xylydine hydrochloride; this leads to an alteration of the proportion of the reactants in the direction of an increased excess of the chloromethylnitrotoluene.

The monoalkylation reaction proceeds with but a 75% yield in the presence of pyridine owing to the side reaction which forms the quaternary salt of pyridine with 2-chloromethyl-4-nitrotoluene. The same reason underlies the fact that the dialkylation reaction almost does not take place in the presence of pyridine.

We showed that the alkylation products of o-4-xylydine by 2-chloromethyl-4-nitrotoluene undergo hydrolysis during the reduction with hydrogen not only in the presence of a palladium catalyst but also over Raney nickel. In the latter instance, it is advised that the reaction be run at the temperature of over 100° under pressure for obtaining a high yield of o-4-xylydine formed in the dealkylation. The use of such conditions for the reduction of 2-chloromethyl-4-nitrotoluene in high concentrations permitted us to prepare o-4-xylydine in a 78% yield.

EXPERIMENTAL

Hydrogenation of 2-chloromethyl-4-nitrotoluene without added pressure. A solution of 50 g of 2-chloromethyl-4-nitrotoluene (b. p. 147-148° at 6 mm; m. p. 61-61.5°) in 1700 ml of alcohol was hydrogenated with 100 g of Raney nickel catalyst and 30 g of sodium acetate until hydrogen ceased to be taken up, after which the catalyst was filtered off. The filtrate was acidified with hydrochloric acid (to Congo red) and the alcohol was distilled off; finally with the aid of steam; the residue was made alkaline with sodium hydroxide (to phenolphthalein) and 15.4 g of o-4-xylydine (47%) with m. p. 48-49° was steam distilled.

The residue after the distillation of xylydine was extracted with 150 ml of benzene, the extract was dried with sodium sulfate, the solvent was distilled off and the dark oil (10.2 g) was vacuum distilled, collecting the fraction boiling at 164-172° at 0.05 mm (3.1 g). 2.4 g of colorless crystals of 2'-methyl-5'-aminobenzyl-o-4-xylydine (IV) with m.p. 66.5-67° was isolated by slow crystallization from a mixture of petroleum ether and benzene (5 : 1).

Analysis for a primary amino group: 0.05 g of the substance in 5 ml of alcohol and 1 ml of saturated alcohol sodium hydroxide solution with a few drops of water and chloroform gave the characteristic isonitrile odor on being heated.

Found %: C 79.98, 80.05; H 8.10, 8.20; N 11.69, 11.56, M 252.37. $C_{16}H_{20}N_2$. Calculated %: C 79.96; H 8.39; N 11.65. M 240.35.

There was obtained after hydrogenation of 2.5 g of 2-chloromethyl-4-nitrotoluene and 2.5 g of sodium acetate in alcohol: at 1.2% concentration with 10 g of Raney nickel catalyst - 1.2 g (73.7%), while with 2.5 g of the catalyst - 1.1 g (67.5%) of o-4-xylydine; at 6% concentration with 10 g of the catalyst - 53%, and with 2.5 g of the catalyst - 20.3% of o-4-xylydine.

N-2'-Methyl-5'-nitrobenzyl-o-4-xylydine (III). A) 42.3 g of o-4-xylydine (II), 55.5 g of 2-chloromethyl-4-nitrotoluene (I) and 42 g of sodium bicarbonate were added to 300 ml of alcohol and the mixture was stirred at the boiling point for four hours. The precipitate was filtered off after cooling and the filtrate was evaporated to dryness under vacuum. The solids were combined and extracted (in a Soxhlet apparatus) with 300 ml of acetone from which crystals (55 g) separated on cooling; the mother liquor after the separation of these crystals was partially evaporated, diluted with hot alcohol and an additional quantity of the product was thus isolated. In all 77.1 g (95%) of (III) was obtained in the form of orange-red elongated prisms with m.p. 116-116.7° (from alcohol).

Found %: C 70.98, 70.74; H 7.05, 6.77; N 10.52, 10.72. $C_{16}H_{18}O_2N_2$. Calculated %: C 71.09; H 6.71; N 10.36.

B) A mixture of 17 g of o-4-xylydine, 25 g of 2-chloromethyl-4-nitrotoluene and 40 ml of pyridine in 150 ml of alcohol was refluxed for five hours. 7.6 g of the quaternary salt of pyridine and 2-chloromethyl-4-nitrotoluene was obtained in the form of colorless prisms (from alcohol) with m. p. 222-223° (with decomposition), after partial evaporation under vacuum (a viscous dark oil) and treatment with 250 ml of cold acetone.

The substance was readily soluble in water, sparingly in cold alcohol and insoluble in acetone. A mixed melting point with the quaternary salt prepared from pyridine and 2-chloromethyl-4-nitrotoluene showed no depression.

Found %: C 58.71, 58.94; H 5.08, 5.12; N 10.60, 10.64; Cl 13.24, 13.40. $C_{15}H_{13}O_2N_2Cl$. Calculated %: C 58.96; H 4.92; N 10.59; Cl 13.40.

28.5 g (75%) of (III) with m. p. 115.5-116.5° (from alcohol) was isolated from the acetone solution; a mixed melting point with compound (III) prepared in the presence of sodium bicarbonate showed no depression.

Hydrochloride (III) was prepared in acetone by the action of an alcoholic solution of hydrogen chloride. The precipitate was recrystallized from alcohol in the presence of a small amount of hydrogen chloride; it formed colorless crystals with m. p. 191-192°.

Found %: N 9.22, 9.34. $C_{16}H_{13}O_2N_2 \cdot HCl$. Calculated %: N 9.16.

Quaternary salt of pyridine and 2-chloromethyl-4-nitrotoluene. 3.9 g of 2-chloromethyl-4-nitrotoluene was dissolved in 10 ml of pyridine, refluxed for one hour, cooled, poured into 50 ml of acetone and the resulting precipitate was filtered off. 5.1 g (93%) of the quaternary salt in the form of colorless prisms (from alcohol) with m. p. 222-223° (with decomposition) was isolated.

Found %: C 58.81, 58.77; H 5.10, 5.16; N 10.35, 10.62; Cl 13.39, 13.18. $C_{15}H_{13}O_2N_2Cl$. Calculated %: C 58.96; H 4.92; N 10.59; Cl 13.40.

N-Bis-(2'-methyl-5'-nitrobenzyl)-o-4-xylidine (V). A) 9.76 g of 2-chloromethyl-4-nitrotoluene was added to a solution of 6.05 g of o-4-xylidine in 150 ml of alcohol and the whole was refluxed for two hours. 3.25 g of (V) crystallized from the solution after two days in the form of thin yellow needles with m. p. 193.5-194° (from alcohol). A mixed melting point with the substance prepared by alkylation of N-2'-methyl-5'-nitrobenzyl-o-4-xylidine (III) with 2-chloromethyl-4-nitrotoluene (I) gave no depression.

Found %: C 69.05, 69.00; H 5.86, 5.83; N 10.25. $C_{24}H_{25}O_4N_3$. Calculated %: C 68.72; H 6.01; N 10.02.

2.4 g of (III) hydrochloride was obtained in the form of colorless crystals with m. p. 191-192° from the mother liquor after concentration to 3/4 of the original volume.

Found %: N 9.40, 9.44. $C_{16}H_{13}O_2N_2 \cdot HCl$. Calculated %: N 9.16.

This hydrochloride was hydrolyzed by being heated with water and gave the free base (III) - orange-red prisms with m. p. 115.5-116.5°.

Found %: N 10.29, 10.16. $C_{16}H_{13}O_2N_2$. Calculated %: N 10.36.

5.8 g of the original 2-chloromethyl-4-nitrotoluene with m. p. 61-61.5° (from alcohol) was obtained from the alcoholic mother liquor after evaporation to dryness and heating the residue with 10% hydrochloric acid, while 3.1 g of o-4-xylidine with m. p. 48-49° was obtained after neutralization of the acidic filtrate.

B) A mixture of 5.7 g of (III), 5 g of 2-chloromethyl-4-nitrotoluene and 5 g of sodium bicarbonate in 25 ml of alcohol was refluxed with stirring for five hours; a formation of a yellow precipitate began during the course of the reaction. The precipitate was filtered off after the reaction mixture had been cooled and the solid was extracted with 300 ml of acetone; the solvent was distilled off until a 50 ml volume remained and, after cooling, 8.4 g of (V) was filtered off in the form of thin yellow needles with m. p. 193.5-194° (from alcohol).

Found %: C 68.51, 68.54; H 6.01, 6.18; N 10.00. $C_{24}H_{25}O_4N_3$. Calculated %: C 68.72; H 6.01; N 10.02.

(V) hydrochloride was isolated by the addition of an alcoholic solution of hydrogen chloride to an acetone solution of the substance; it formed colorless needles with m. p. 174-175°. It hydrolyzed readily during recrystallization.

Found %: N 9.23, 9.31. $C_{24}H_{25}O_4N_3 \cdot HCl$. Calculated %: N 9.22.

N-2'-methyl-5'-aminobenzyl-o-4-xylydine (IV). 73.2 g of N-2'-methyl-5'-nitrobenzyl-o-4-xylydine (III) in 800 ml of alcohol was hydrogenated over 70 g of Raney nickel catalyst; an almost theoretical volume of hydrogen was taken up. The solution was filtered, the alcohol was distilled off under vacuum and 63.5 g (97%) of an oily substance was obtained which was crystallized from a mixture (1 : 5) (200 ml) of boiling benzene and petroleum ether; 29 g of (IV) was obtained after cooling. The mother liquor was evaporated and the residue was distilled at 161-176°, at 1 mm; the substance was recrystallized and 13.1 g of diamine (IV) was additionally isolated.

2.8 g of o-4-xylydine (4.2%) was isolated by steam distillation from the fore-run (45-151° at 0.1 mm).

N-2'-methyl-5'-aminobenzyl-o-4-xylydine crystallizes in the form of colorless prisms with m. p. 66.8-67.3° (from a mixture of benzene and petroleum ether).

Found %: C 80.51, 80.53; H 8.36, 8.29; N 11.42. $C_{16}H_{20}N_2$. Calculated %: C 79.96; H 8.39; N 11.65.

(IV) dihydrochloride precipitated in the form of colorless crystals from the ethereal solution of diamine (IV) by the action of an alcoholic solution of hydrogen chloride; the substance decomposes above 180°.

Found %: N 9.07. $C_{16}H_{20}N_2 \cdot 2HCl$. Calculated %: N 8.94.

The theoretical volume of hydrogen was absorbed in catalytic hydrogenolysis of 2.7 g of (III) over 0.2 g of Pd-BaSO₄ (10%) in 50 ml of alcohol. 2.3 g (96.4%) of o-xylydine with m. p. 48-49° (from petroleum ether) was isolated by means of a steam distillation of the residue after the removal of the solvent. Hydrogenolysis of 1 g of (IV) over 1 g of Raney nickel catalyst in 20 ml of alcohol at 100° and 50 atm over one hour gave 0.9 g (90%) of o-4-xylydine.

N-Bis-(2'-methyl-5'-aminobenzyl)-p-4-xylydine (VI). A suspension of 3 g of (V) in 50 ml of alcohol was hydrogenated over 3 g of this nickel catalyst. The starting material dissolved completely toward the end of the reaction, while a precipitate crystallized on the walls of the hydrogenation vessel. The solution was heated, filtered from the catalyst and evaporated under vacuum to the volume of 7 ml. 1.7 g of product was filtered off after cooling, while 2.2 g (85.3%) of (VI) was obtained in all after the working up of the mother liquors; this formed colorless crystals with m. p. 161-163° (from alcohol).

Found %: C 80.02, 80.08; H 8.45, 8.41; N 11.55, 11.70. $C_{24}H_{28}N_4$. Calculated %: C 80.18; H 8.13; N 11.69.

0.2 g of o-4-xylydine (7.7%) was obtained by steam distillation from the mother liquors.

In the catalytic hydrogenolysis of 2.6 g of (V) with 0.2 g of Pd/BaSO₄ (10%) in 50 ml of alcohol there was obtained a solution from which 2.1 g of o-4-xylydine (93.3%) with m. p. 48-49° (from petroleum ether) was isolated by steam distillation after the removal of the alcohol.

Hydrogenation of 2-chloromethyl-4-nitrotoluene under pressure. 12 g of 2-chloromethyl-4-nitrotoluene and 12 g of sodium acetate in 60 ml of alcohol was hydrogenated over 12 g of Raney nickel catalyst at 120° and 80 atm pressure (initial) in a 150 ml autoclave over 3 hours. 6.1 g of o-4-xylydine (78.2%) with m. p. 48-49° was steam distilled after the removal of the catalyst and of the solvent.

SUMMARY

1. It was shown that the catalytic hydrogenation of 2-chloromethyl-4-nitrotoluene to o-4-xylydine is accompanied by a secondary reaction of alkylation of the aromatic amine by the as yet unreduced haloalkyl aromatic nitro compounds.
2. It was established that, under the conditions which are favorable for dealkylation of the by-products of the reaction, 2-chloromethyl-4-nitrotoluene undergoes a catalytic hydrogenation over Raney nickel catalyst to o-4-xylydine in 78% yield.
3. Five new, previously undescribed bases were prepared.

LITERATURE CITED

[1] K. Sahashi, H. Akamatsu, and H. Genda, Bull. Inst. Phys. Chem. Research (Tokyo) 24, 72 (1948); G. A., 42, 5458 (1948).

[2] V. M. Berezovskii, V. A. Kurdyukova, and N. A. Preobrazhenskii, J. Gen. Chem. 21, 1163 (1951).*

Received March 6, 1958

* Original Russian pagination. See C.B. Translation.

SOME NEW ACID AMIDES - PLANT GROWTH REGULATORS

K. S. Bokarev

Plant Physiology Institute of the Academy of Sciences, USSR

An interest in the study of various amides of halophenoxyalkylcarboxylic acids has been rising in recent years in connection with the problem of the mechanism of action of these acids. It is regarded that the activity of the halophenoxyalkylcarboxylic acids is connected with the presence of the carboxy group in their molecules; hence, the activity of the amides of these acids depends on the transformation of these into the corresponding acids [1, 2].

A large number of various substituted amides of acids have been described at this time as having the properties of growth regulators [2]. Some halophenoxyacyl derivatives of amino acids were synthesized recently [3-7], on plant testing of which it appeared that some of these amides were close in activity to the corresponding halophenoxyacetic acids while others were considerably less active or completely inactive.

The above data indicate that either the plants are incapable of hydrolyzing some of the amides or the activity of the compounds depends on some specific peculiarities of the structure of the molecule as a whole and on the ability of these to move in the plant [6,7]. It was rational, therefore, to study the problem of the physiological activity of othersubstituted acid amides - plant growth regulators.

We synthesized for this purpose some N-acyl derivatives of p-aminobenzoic and anthranilic acids in which the acyl groups were represented by the residues of 2,4-dichlorophenoxyacetic, 2,4,5-trichlorophenoxyacetic, α -naphthylacetic, 3,6-endoxohexahydrophthalic, 2,3,5-triodobenzoic, 2,4,5-trichlorophenoxy- α -isobutyric, and phenylcarbamic acids. In addition, we prepared the ethyl esters of phenylcarbamyl- and phenylthiocarbamyl-p-aminobenzoic acids.

N-Phenylcarbamyl-p-aminobenzoic acid, prepared by the reaction of phenyl isocyanate and p-aminobenzoic acid [8], is the only substance among the compounds prepared by us that has been described in the literature. There are some data on testing N-2,4-dichlorophenoxyanthranilic acid [9] on plants, but the preparation of this substance has not been described.




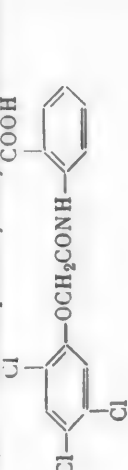
2,4-Dichlorophenoxyacetyl-, 2,4,5-trichlorophenoxyacetyl-, 2,4,5-trichloro- α -phenoxyisobutyryl-, α -naphthylacetyl- and 2,3,5-triodobenzoyl-p-aminobenzoic, as well as 2,4-dichlorophenoxyacetyl-, 2,4,5-trichlorophenoxyacetyl- and α -naphthylacetylanthranilic acids were synthesized by the reaction of the acyl chlorides with the appropriate aminobenzoic acids in an alkaline solution (see table).





Ethyl esters of phenylcarbamyl- and phenylthiocarbamyl-p-aminobenzoic acids were prepared by heating phenyl isocyanate or phenyl isothiocyanate with the ethyl ester of p-aminobenzoic acid.

Phenylcarbamyl-p-aminobenzoic acid was prepared by saponification of its ethyl ester by means of potassium hydroxide solution in methyl alcohol.

The acid p-carboxyanilide of 3,6-endoxohexahydrophthalic acid was synthesized by the reaction of the anhydride of this acid with p-aminobenzoic acid in dioxane solution at room temperature. This amide, like the previously described arylamides of some substituted 3,6-endoxohexahydrophthalic acids [10], is transformed into the p-carboxyphenylimide of 3,6-endoxohexahydrophthalic acid on being heated or recrystallized from hot solvents by a loss of one molecule of water. The p-carboxyphenylimide is formed directly on heating of a suspension of 3,6-endoxohexahydrophthalic anhydride and p-aminobenzoic acid in benzene, xylene or acetic acid.

N-Acylaminobenzoic Acids and Their Properties

Name and formula	Am'ts of starting materials				Yield		M. P.	Analysis for nitrogen (%)	
	aminobenzoic acid		acyl chloride		in g	in %		found	calculated
	in g	in g-moles	in g	in g-moles					
2,4-Dichlorophenoxyacetyl-p-aminobenzoic acid 	6.86	0.05	11.98	0.05	14.3	84.1	267°	4.40, 4.20	4.12
2,4-Dichlorophenoxyacetylanthranilic acid 	6.86	0.05	11.98	0.05	12.7	74.7	219—219.5	4.25, 4.06	4.12
2,4,5-Trichlorophenoxyacetyl-p-amino-benzoic acid 	6.86	0.05	13.66	0.05	14.8	79.0	289—290	3.88, 3.89	3.74
2,4,5-Trichlorophenoxyacetylanthranilic acid 	6.86	0.05	13.66	0.05	14.3	76.3	278—280	3.88, 3.65	3.74

Name and formula	Am'ts of starting materials				Yield		M. P.	Analysis for nitrogen (%)	
	aminobenzoic acid		acyl chloride		in g	in %		found	calculated
	in g	in g-moles	in g	in g-moles					
2,4,5-Trichlorophenoxy- α -isobutyryl-p-aminobenzoic acid 	6.86	0.05	15.06	0.05	17.4	86.4	233°	3.62, 3.60	3.48
α -Naphthylacetyl-p-aminobenzoic acid 	6.86	0.05	10.23	0.05	11.9	78.0	271—272	4.50, 4.62	4.59
α -Naphthylacetyl-p-aminobenzoic acid 	6.86	0.05	10.23	0.05	8.7	57.0	220	4.49, 4.50	4.59
2,3,5-Triiodobenzoyl-p-aminobenzoic acid 	3.43	0.025	12.96	0.025	11.8	76.3	221 (with decomposition)	2.12, 2.18	2.26

Analysis for nitrogen (%)

The acids synthesized by us, except for the derivatives of 3,6-endoxohexahydrophthalic acid, are poorly soluble in water and the usual organic solvents, and are more soluble in dimethylformamide. They are weak acids and they could not be titrated in the presence of phenolphthalein. The potassium salts of these acids are poorly soluble in water. The acids synthesized by us sublime at elevated temperatures and for this reason their melting points were determined in sealed capillaries.

EXPERIMENTAL

Preparation of acyl chlorides. The chlorides of 2,4-dichlorophenoxyacetic, 2,4,5-trichlorophenoxyacetic, 2,3,5-triiodobenzoic and α -naphthylacetic acids were prepared according to methods described in the literature from the respective acids and thionyl chloride [3, 11, 12].

The previously undescribed 2,4,5-trichlorophenoxy- α -isobutyryl chloride was synthesized by refluxing 213 g of the acid (m. p. 92°) with 595 g of thionyl chloride for six hours. The excess thionyl chloride was distilled off, after the termination of heating, first at atmospheric pressure, then under the usual vacuum. The residue (200 g) was distilled at 1 mm in the form of a colorless oil with b. p. 140-141°. The chloride crystallized after standing for several hours and was then recrystallized twice with considerable losses from *n*-heptane. M. p. 32°.

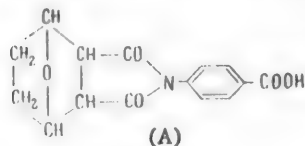
The acyl chloride chlorine was determined by the Volhard method after hydrolysis of the chloride with an alcoholic potassium hydroxide solution.

Found %: Cl 11.65, 11.70. $C_{10}H_8O_2Cl_4$. Calculated %: Cl 11.74.

Exo-cis-3,6-endoxohexahydrophthalic anhydride was prepared by heating the acid with acetyl chloride according to a literature method [13].

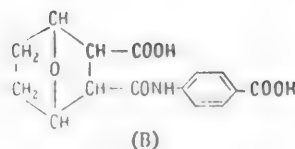
Preparation of halophenoxyacyl-, α -naphthylacetyl- and 2,3,5-triiodobenzoylaminobenzoic acids (see table). A solution of 0.05 mole of the chloride of the appropriate acid in 50 ml of benzene (the 2,3,5-triiodobenzoyl chloride was dissolved in 100 ml of ether) was added dropwise with stirring over 30 minutes to the solution of 6.86 g of the aminobenzoic acid and 6 g of sodium hydroxide in 150 ml of distilled water cooled to the temperature of -2° to +3°. The mixture was stirred for 30 minutes longer after the completion of the addition of the acyl chloride, after which the ice bath was removed and the mixture was stirred for two hours longer at room temperature. The resulting precipitate of acylaminobenzoic acid salt was dissolved in the necessary volume of distilled water and the solution was subjected to three extractions with ether (25 ml each). The aqueous solution was acidified by means of hydrochloric acid to Congo red. The resulting precipitate was filtered off, washed with water, dried and recrystallized from a suitable solvent.

Exo-cis-3,6-endoxohexahydrophthalic p-carboxyphenylimide (A). A suspension of 20.18 g of 3,6-endoxohexahydrophthalic anhydride and 13.71 g of p-aminobenzoic acid in 200 ml of benzene was refluxed for 12 hours. The reaction product was filtered off and dried at 120°. Yield:



28.1 g (99.3%). 7 g of the resulting substance was heated on a steam bath with 50 ml of dimethylformamide and the undissolved residue (5.2 g) was recrystallized twice from 350 ml of water. Yield: 1.8 g. M. p. 264°. The same substance was also formed on heating the suspension of the starting materials in xylene or in acetic acid.

Found %: N 5.04, 5.03. Equiv. 285.6, 285.8. $C_{15}H_{13}O_5N$. Calculated %: N 4.88. Equiv. 287.2.

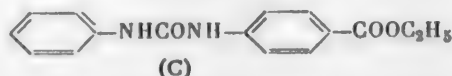


Acid exo-cis-3,6-endoxohexahydrophthalic p-carboxyanilide (B). A solution of 13.71 g of p-aminobenzoic acid in 110 ml of dioxane was added with stirring at room temperature to a solution of 16.81 g of 3,6-endoxohexahydrophthalic acid in 60 ml of dioxane. The mixture was stirred for one hour, the resulting precipitate was filtered off, washed with dioxane and dried. Yield: 30 g (98.2%). 10 g of the substance was shaken with 500 ml of acetone for six hours. The undissolved residue was filtered off and dried. Yield: 7.8 g. Part of this residue (4.5 g) was dissolved in 35 ml

of cold dimethylformamide and 220 ml of carbon tetrachloride was added to the solution. Yield: 4.2 g. M. p. 263°. (The acid amide changes into the amide on being heated during the determination of its melting point.)

Found %: N 4.60, 4.53. Equiv. 155.9, 155.8. $C_{15}H_{15}O_2N$. Calculated %: N 4.59. Equiv. 152.6.

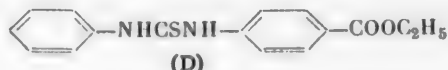
Ethyl ester of N-phenylcarbamy-p-aminobenzoic acid (C).



15 g of phenyl isocyanate was added to the solution of 21.24 g of ethyl p-aminobenzoate in 50 ml of benzene heated to boiling. The mixture was refluxed for one hour. The resulting precipitate of the ester was filtered off after cooling, washed with benzene and dried. Yield: 33.4 g (93.4%). The substance was recrystallized from a mixture of 50 ml of benzene and 65 ml of ethylene chloride. Yield: 32.4 g. 29.7 g of the substance with m. p. 163° was obtained after recrystallization from a mixture of 100 ml of ligroin (b. p. 75-100°) and 220 ml of ethylene chloride.

Found %: N 9.88, 9.71. $C_{16}H_{15}O_3N_2$. Calculated %: N 9.85.

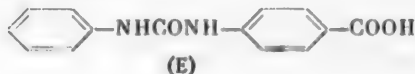
Ethyl ester of phenylthiocarbamy-p-aminobenzoic acid (D). This was prepared similarly to the ethyl ester of phenylcarbamy-p-aminobenzoic acid from 20.28 g of phenyl isothiocyanate and 26.43 g of ethyl p-aminobenzoate in 50 ml of benzene. Yield: 37.2 g (82.6%). The resulting ester was recrystallized from a



mixture of 50 ml of ligroin (b. p. 100-125°) and 20 ml of benzene (the yield was 31.5 g), then from a mixture of 50 ml of ligroin and 10 ml of ethylene chloride. Yield: 26.0 g. M. p. 116°.

Found %: N 9.20, 9.13. $C_{16}H_{15}O_3N_2S$. Calculated %: N 9.33.

Phenylcarbamy-p-aminobenzoic acid (E).



A solution of 2.25 g of potassium hydroxide in 5 ml of water and 20 ml of methyl alcohol was added to a hot solution of 7.1 g of ethyl phenylcarbamy-p-aminobenzoate in 50 ml of methyl alcohol. The mixture was refluxed for five hours. The precipitate of the salt was filtered off (yield of the salt; 5.9 g) and dissolved in 300 ml of boiling distilled water. The solution was acidified with hydrochloric acid after cooling, the resulting precipitate of the acid was filtered off, washed with water and dried. Yield: 5.2 g. The filtrate from the salt was diluted with 400 ml of water and acidified with hydrochloric acid. An additional 1.1 g of the acid was thus obtained. The total yield of phenylcarbamy-p-aminobenzoic acid was 6.3 g (98.4%). 2.6 g of the pure acid was obtained after two recrystallizations from a mixture of 50 ml of methyl alcohol and 22 ml of dimethylformamide. M. P. 300°. (with decomposition). It sublimes at 255°. According to the literature data [8]: m. p. 297-300°.

Found %: N 10.88, 10.90. $C_{14}H_{12}O_3N_2$. Calculated %: N 10.93.

SUMMARY

13 acyl derivatives of p-aminobenzoic and anthranilic acids were synthesized for the purpose of studying the mechanism of action of plant grown stimulators; twelve of these compounds have not been described in the literature previously.

LITERATURE CITED

- [1] H. Veldstra, *Ann. Rev. Plant Physiol.* 4, 151 (1953).
- [2] N. N. Mel'nikov, Yu. A. Baskakov, and K. S. Bokarev, *Chemistry of Herbicides and Plant Growth Stimulators*, Moscow State Chem. Press, 382 (1954).*
- [3] J. W. Wood and T. D. Fontaine, *J. Org. Ch.* 17, 891 (1952).
- [4] C. F. Krewson, C. H. H. Neufeld, T. F. Drake, T. D. Fontaine, J. W. Mitchell, and W. H. Preston, *Weeds* 3, 28 (1954).
- [5] K. S. Bokarev and N. N. Mel'nikov, *J. Gen. Chem.* 25, 2493 (1955).**
- [6] C. F. Krewson, T. F. Drake, C. H. H. Neufeld, T. D. Fontaine, J. W. Mitchell, and W. H. Preston, *J. Agr. Food Chem.* 4, 140 (1956).
- [7] C. F. Krewson, T. F. Drake, J. W. Mitchell, and W. H. Preston, *J. Agr. Food Chem.* 4, 690 (1956).
- [8] R. N. Lastovskii, *J. Gen. Chem.* 18, 921 (1948).
- [9] H. E. Thompson, C. P. Swanson, and A. G. Norman, *Botan. Gaz.* 107, 476 (1946).
- [10] N. N. Mel'nikov and V. A. Kraft, *J. Gen. Chem.* 26, 213 (1956). **
- [11] C. J. Klemme and J. H. Hunter, *J. Org. Ch.* 5, 508 (1940).
- [12] D. Liberman, J. Himbert, and L. Hengl, *Bull. Soc. Chim.* 1950, 486.
- [13] O. Diels and K. Alder, *Ber.* 62, 544 (1929).

Received March 2, 1958

* In Russian.

** Original Russian pagination. See C.B. Translation.

REDUCTION OF DERIVATIVES OF α,β -UNSATURATED ACIDS ON THE DROPPING MERCURY CATHODE

I. DERIVATIVES OF FUMARIC ACID

I. A. Korshunov, Yu. V. Vodzinskiĭ, N. S. Vyazankin, and
A. I. Kalinin

Research Institute of Chemistry at the Gorkii State University

The problem of the effect of the structure of organic compounds on their ability to be reduced on the mercury cathode has been discussed frequently in the literature. J. Heirowsky [1] considers that the main factor which affects the ease of reduction is the polarizability of the molecule, i.e., its ability to redistribute its electron density at the instant of reaction. In opposition to this, S. A. Voitkevich [2] comes to the conclusion about the direct dependence of the half-wave reduction potential on the polarity of the molecule by a comparison of the half-wave potentials and the dipole moments.

Insofar as the reactivity of a molecule is determined by the nature of the atoms composing it, by the character of the bond between them, by its polarity and polarizability as well as by a number of other factors, it is natural to allow that only after a combined examination of these factors is it possible to draw a conclusion about the ease of the reduction of this molecule. Another approach to the solution of this problem may lead to erroneous conclusions as it seems to us.

For example, it is known that nitriles of acrylic and methacrylic acids have large dipole moments than the corresponding methyl esters of these acids. However, judging by the half-wave potentials, the nitriles are reduced at more negative potentials than are the corresponding esters. The number of such examples may be readily multiplied.

Considering that the clarification of the effect of structure of organic compounds on their ability to be reduced is sufficiently important, it seemed natural to us to find the dependence between the half-wave reduction potential and the character of conjugation in α,β -unsaturated acids and their derivatives. For this purpose we studied the polarographic reduction of a series of fumaric acid derivatives.

Reduction of fumaric and maleic acids, their esters and salts on the dropping mercury cathode has been studied by many authors [3-5] who determined the values of the half-wave potentials and the number of electrons participating in the reduction.

The value of the half-wave potential for fumaric acid is somewhat greater than for maleic acid, under otherwise same conditions. The values of $E_{1/2}$ for the diethyl esters of these acids are approximately equal while for low pH values the $E_{1/2}$ of diethyl fumarate is even slightly smaller than that for the ester of maleic acid. Schemes of the mechanism of reduction have been proposed for maleic and fumaric acids. The existence of a direct proportionality between the height of the polarographic wave and the concentration of the molecule being reduced has been established.

The polarographic reduction of fumarodinitrile was studied by M. I. Bobrova and A. N. Matveeva [6] on the background of an aqueous solution of tetraethylammonium iodide. The drawing of the polarogram of the dinitrile shown in their paper resembles only rather remotely the generally known form of the polarization curves.

The half-wave potential of fumarodinitrile changes very greatly with an insignificant increase of the concentration, the change being from -1.48 to -1.84 v, which is not observed in the case of pure compounds. It is natural to suppose that the above authors were dealing with a contaminated or a decomposed substance.

We obtained different results in the reduction of fumarodinitrile on a dropping mercury cathode, the purity of the substance being confirmed by an elemental analysis.

EXPERIMENTAL

Synthesis of Derivatives of Fumaric Acid.

Synthesis and purification of dimethyl ester, monoethyl ester, diamide and dinitrile of fumaric acid were done according to the recipes given in the existing literature [7-9]. Fumarodinitrile was purified by two recrystallizations from alcohol. M. p. 96°.

Found %: C 61.62, 61.82; H 2.65, 2.69; N 36.10, 36.02. $C_4H_2N_2$. Calculated %: C 61.54; H 2.58; N 35.87.

The following derivatives of fumaric acid have not been described previously as far as this is known to us.

β -Carbethoxyacrylic acid diethylamide. 50.3 g (0.688 mole) of diethylamine in 50 ml of benzene was dropwise with ice cooling to a solution of 55.8 g (0.344 mole) of β -carbethoxyacrylyl chloride [8] in 150 ml of anhydrous benzene.

After the completion of the addition, the mixture was heated for two hours on a water bath. 200 ml of water was added to the cooled solution. The benzene layer was separated and washed successively with dilute hydrochloric acid, water, 5% sodium carbonate solution, and water. After drying over calcium chloride, benzene was distilled off and the residue was fractionated under vacuum. The yield of β -carbethoxyacrylic acid diethylamide was 40.6 g (58.2%).

B. p. 101-102° (1 mm), 118-120° (2 mm), n_D^{20} 1.4795, d_4^{20} 1.0299.

Found %: C 59.98, 60.07; H 8.53, 8.68; N 7.14, 7.09. $C_{10}H_{17}O_3N$. Calculated %: C 60.28; H 8.60; N 7.02.

β -Carbethoxyacrylic acid dimethylamide. This was synthesized by a method similar to that described above from 0.2 mole of β -carbethoxyacrylyl chloride, dissolved in 100 ml of absolute ether, and 0.4 mole of dimethylamine in 50 ml of ether. The yield of β -carbethoxyacrylic acid dimethylamide was 23.4%

B. p. 118-119° (4 mm), n_D^{20} 1.4798, d_4^{20} 1.0783.

Found %: C 55.91, 56.04; H 7.73, 7.75; N 8.32, 8.17. $C_8H_{13}O_3N$. Calculated %: C 56.16; H 7.60; N 8.18.

β -Carbethoxyacrylic acid Dibutylamide. 26.0 g (0.2 mole) of dibutylamine in 50 ml of ether was dropwise with ice cooling to a solution of 16.3 g (0.1 mole) of β -carbethoxyacrylyl chloride in 100 ml of absolute ether. β -Carbethoxyacrylic acid dibutylamide was obtained after the usual working-up. Yield: 73.6%.

B. p. 138-140° (0.5 mm), n_D^{20} 1.4736, d_4^{20} 0.9790.

Found %: C 65.43, 65.58; H 9.71, 9.75; N 5.21, 5.32. $C_{14}H_{25}O_3N$. Calculated %: C 65.85; H 9.87; N 5.48.

β -Carbethoxyacrylic acid diphenylamide. 8.0 g (0.05 mole) of diphenylamine and 6.2 g (0.05 mole) of dimethylaniline were dissolved in 50 ml of absolute ether. 8.1 g (0.05 mole) of β -carbethoxyacrylyl chloride in 25 ml of absolute ether was added dropwise with water cooling to this solution. The mixture was refluxed for one hour, washed successively with water, dilute hydrochloric acid, sodium carbonate solution and water. After drying over calcium chloride, the ethereal solution was evaporated until crystallization of β -carbethoxyacrylic acid diphenylamide began. Yield: 77.4%. M. p. 74-75° (from alcohol).

Found %: C 73.65, 73.56; H 5.76, 5.71; N 4.65, 4.80. $C_{18}H_{17}O_3N$. Calculated %: C 73.20; H 5.80; N 4.74.

β -Carbethoxyacrylamide. This was prepared by saturation of an ice-cooled solution of 0.3 mole of β -carbethoxyacrylyl chloride in 250 ml of anhydrous benzene with ammonia, with a subsequent refluxing (0.5 hour) and filtration of the boiling reaction mixture. The product which remained on the filter was extracted three times with hot benzene. The benzene solutions were combined and evaporated under vacuum. The yield of β -carbethoxyacrylamide was 62.1%. M. p. 99-100°.

Found %: C 50.01, 50.12; H 6.37, 6.39; N 9.59, 9.54. $C_6H_9O_3N$. Calculated %: C 50.34; H 6.34; N 9.78.

β -Carbethoxyacrylonitrile. A mixture of 28.6 g (0.2 mole) of β -carbethoxyacrylamide and 42.5 g of phosphorus pentoxide was placed in a Claisen flask arranged as a vacuum distillation apparatus. The mixture was heated on an oil bath at 10 mm pressure until the dehydration process was complete. The dehydration product collected in the receiver was fractionated under vacuum. Yield: 77.1%.

B. p. 53° (4 mm) and 83.5° (16 mm), n_D^{20} 1.4503, d_4^{20} 1.0542.

Found %: C 57.01, 56.93; H 5.57, 5.60; N 10.69, 10.81. $C_6H_7O_2N$. Calculated %: C 57.59; H 5.63; N 11.19.

Polarographic Study of Derivatives of Fumaric Acid.

The study of the reduction of fumaric acid derivatives on a dropping mercury cathode was done on a polarograph M-8 designed by the Gorkii Research Institute of Chemistry, the galvanometer of which had the sensitivity of $2.4 \cdot 10^{-3}$ A/mm. The capillary characteristic $m^{2/3} t^{1/6} = 1.40 \text{ mg}^{2/3} \text{ sec}^{-1/2}$. Aqueous 0.2 N solutions of hydrochloric acid, lithium chloride, and lithium hydroxide were used as the indifferent electrolytes. The polarography was run at the temperature $25 \pm 0.3^\circ$. As indicated by the existing studies made on similar substances, more drastic conditions of thermostating could not be employed. The polarographic maxima observed from some of the substance being studied were readily suppressed by the addition of a drop of 1% gelatin solution to the electrolyzing vessel.

The results of the polarographic study of fumaric acid derivatives are assembled in the table. All values of $E_{1/2}$ shown there were determined relative to a saturated calomel electrode and correction were made for the i_r of the electrolysis vessel.

The numerical values of i_d/c were obtained as averages of several determinations. The constancy of the ratio i_d/c within the interval of concentrations from 2 to 20 millimoles/liter indicates the possibility of a quantitative determination of these substances by the polarographic method in acid and neutral background media. The alkaline backgrounds cannot be used for these purposes since some of the substances are subject to rather rapid hydrolysis in them.

Since fumarodinitrile decomposes rapidly in aqueous and alcoholic solutions, its solutions were prepared directly before their being polarographed. The results of the polarographic study are given in the table. The polarogram of fumarodinitrile is shown in the figure. For a comparison with the results obtained by M. I. Bobrova and A. N. Matveeva, we took the polarization curves on the background of an aqueous solution of tetraethylammonium iodide which coincided with the polarization curves obtained on the background of 0.2 N lithium chloride solution in respect to the shape of the polarization curve (2 waves), the magnitudes of the limiting current and the halfwave potentials.

All the above material allows us to assert that the data obtained by M. I. Bobrova and A. N. Matveeva for fumarodinitrile are erroneous.

A third wave appeared in the reduction of β -carbethoxyacrylonitrile with the background on 0.2 N lithium chloride at concentrations greater than 5 millimoles/liter. Evidently, this diffusional wave belongs to a very small but polarographically active impurity which could not be eliminated in the course of purification.

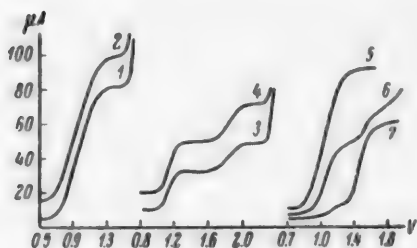
Reduction of the derivatives of α, β -unsaturated acids studied by us on the dropping mercury cathode proceeded differently depending on their composition. The appearance of two diffusional waves was observed by us for a number of compounds in neutral and alkaline media (fumarodinitrile, β -carbethoxyacrylic acid and β -carbethoxyacrylonitrile). The causes of the two-step reduction will be discussed by us in another paper.

Results of Polarography of Fumaric Acid Derivatives

No. in order	Formula of substance	Background: 0.2N hydrochloric acid solution		Background: 0.2N lithium chloride solution		Background: 0.2 N lithium hydroxide solution		Remarks
		$-E_{1/2}$	i_d/c	$-E_{1/2}$	i_d/c	$-E_{1/2}$	i_d/c	
1	$\text{CH}_3\text{OOC}-\text{CH}=\text{CH}-\text{COOCH}_3$	0.68	4.34	1.06	3.87	1.83	2.48	Hydrolyzes in alkaline medium
2	$\text{H}_2\text{NOC}-\text{CH}=\text{CH}-\text{CONH}_2$	0.64	3.97	1.18	4.10	1.24	4.51	
3	$\text{NC}-\text{CH}=\text{CH}-\text{CN}$	0.97	7.20	I 1.14, II 1.86	2.44, 1.83	1.16	2.42	
4	$\text{C}_2\text{H}_5\text{OOC}-\text{CH}=\text{CH}-\text{COOH}$	0.66	3.22	I 0.84, II 1.48	2.38	1.80	2.82	The second wave is 4 times smaller in its heights than the first wave with the background electrolyte being 0.2N lithium chloride
5	$\text{C}_2\text{H}_5\text{OOC}-\text{CH}=\text{CH}-\text{CN}$	0.78	7.25	I 1.11, II 1.32	2.37, 1.46	I 1.57, II 1.94	2.22, 2.03	
6	$\text{C}_2\text{H}_5\text{OOC}-\text{CH}=\text{CH}-\text{CONH}_2$	0.65	4.24	1.16	3.95	1.48	4.00	With 0.2N lithium chloride background electrolyte and at concentration greater than 5 millimoles/liter a small third wave appears with $E_{1/2} = -1.88$ v.
7	$\text{C}_2\text{H}_5\text{OOC}-\text{CH}=\text{CH}-\text{CON}(\text{CH}_3)_2$	0.72	2.32	1.21	2.26	1.64	2.20	
8	$\text{C}_2\text{H}_5\text{OOC}-\text{CH}=\text{CH}-\text{CON}(\text{C}_2\text{H}_5)_2$	0.64	2.42	1.23	2.42	1.56	2.01	
9	$\text{C}_2\text{H}_5\text{OOC}-\text{CH}=\text{CH}-\text{CON}(\text{C}_4\text{H}_9-\text{n.})_2$	0.66	1.32	1.30	2.16	1.74	1.75	Taken in 25% alcohol solution
10	$\text{C}_2\text{H}_5\text{OOC}-\text{CH}=\text{CHCON}(\text{C}_6\text{H}_5)_2$	0.64	2.72	1.12	3.18	1.40	2.6	Taken in 50% alcohol solution

DISCUSSION OF THE RESULTS

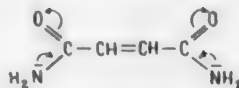
The experimental material existing in the literature indicates that the reduction of organic compounds proceeds at less negative potentials with the growth of the conjugated system of the π -bonds [10, 11]. This may evidently explain the fact that fumaric acid and its derivatives in which the conjugation of π -electrons of two carbonyl groups and the ethylene bond occurs are reduced more readily than are the corresponding derivatives of acrylic acid in which the C=C bond is conjugated with but one carbonyl group.



Polarograms of fumarodinitrile on the background of 0.2 N solutions of: HCl (1, 2), LiCl (3, 4) and LiOH (5-7). Concentration (millimoles / liter): 1) 9.09; 2) 13.0; 3) 9.40; 4) 13.0; 5) 33.0. Curve 6) fumarodinitrile after 2 hours of hydrolysis in 0.2 N LiOH; 7) same after 12 hours.

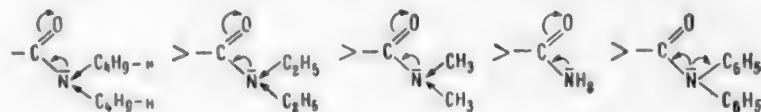
In all the compounds, which were subjected by us to the polarographic study, there is a system of three conjugated π -bonds: $O=C-C=C-C=O$ or $N\equiv C-C=C-C\equiv N$.

It is possible to suppose in the comparison of the magnitude of the conjugation of the system of π -bonds in the dimethyl ester and the diamide of fumaric acid that this would be somewhat weakened in the diamide owing to the competing conjugation of the unshared electron pairs of nitrogen atoms with the π -electrons of the carbonyl groups.



In accord with this supposition, the fumarodiamide is reduced more difficultly than in the dimethyl ester on the background of lithium chloride. The connection between the character of the conjugated system and the ease of reduction is displayed more clearly in the examination of the results of polarographic examination of the amide and the substituted amides of β -carbethoxyacrylic acid.

Since it has been established at this time by several independent methods [12] that the positive inductive effect (decrease of electronegativity) rises in the series $H < CH_3 < C_2H_5 < n-C_3H_7 < n-C_4H_9$ while phenyl shows a negative inductive effect, it is possible to say that the interaction of the free electron pair of the nitrogen atom with the π -bond of the carbonyl group would be decreased in the following order:



Therefore, one should expect that the competing conjugation would be shown most strongly in β -carbethoxyacrylic acid dibutylamide and, conversely, it would be smallest in the case of the diphenylamide of this acid. It is evident from the table that in accord with the above considerations the ease of reduction declines in the series: diphenylamide > amide > dimethylamide > diethylamide > dibutylamide of β -carbethoxyacrylic acid.

At the same time it is clear from the results obtained by us that other factors may also exert a certain influence on the magnitude of the half-wave reduction potential. Such factors are: adsorption on the mercury surface, size and composition of the molecule and others. Thus, for example, monoethyl ester of fumaric acid which should possess a competing conjugation in the carboxyl group is reduced more readily than is the dimethyl ether of this acid.



Conversely, fumarodinitrile and β -carbethoxyacrylonitrile (in this case it is impossible to speak of the existence of a competing conjugation) are reduced more difficultly than is diethyl fumarate.

It is evident from the experimental data given in the Table that the effect of the conjugation of a system of π -bonds on the magnitude of the halfwave potential is displayed particularly clearly in neutral and alkaline media. These regularities are not observed for the same substances on the background of 0.2 N hydrochloric acid, i.e., the nature of the conjugated system of π -bonds in the molecule which is being reduced does not affect in this case the magnitude of the halfwave potential. It is possible to suppose that one of the reasons for this lies in the high hydrogen ion concentration the role of which in the electroreduction reaction is considerable.

SUMMARY

1. The previously undescribed fumaric acid derivatives were prepared and characterized: amide, dimethylamide, diethylamide, dibutylamide, diphenylamide and nitrile of β -carbethoxyacrylic acid.

2. A polarographic study was made of dimethyl ester, monoethyl ester, diamide and dinitrile of fumaric acid as well as of the above-shown derivatives of β -carbethoxyacrylic acid.

3. It was shown that the ease of reduction decreases in the series: diphenylamide > amide > dimethylamide > diethylamide > dibutylamide of β -carbethoxyacrylic acid, which fact is in complete agreement with the character of the conjugated system of π -bonds in these compounds.

LITERATURE CITED

- [1] J. Heyrowsky, Polarographic Method, Theory and Practical Application. State Chem. Tech. Press-Theoret. Chem., p. 47 (1937). *
- [2] S. A. Voitkevich, J. Phys. Chem. USSR 26, 869 (1952).
- [3] B. Warsowsky, P. T. Elving, and T. Mandel, Anal. Chem. 19, 161 (1947).
- [4] P. T. Elving and C. Teitelbaum, J. Am. Chem. Soc. 71, 3916 (1949).
- [5] P. T. Elving and I. Rosental, Anal. Chem. 26, 1454 (1954).
- [6] M. I. Bobrova and A. N. Matveeva, J. Gen. Chem. 27, 1137 (1957). **
- [7] Anschütz, Ber. 12, 2283 (1879).
- [8] V. Eisner, J. A. Elvidge, and R. P. Linstead, J. Chem. Soc. 1951, 1501.
- [9] Syntheses of Organic Preparations (USSR ed.) 4, 364 (1953).
- [10] I. M. Kolthoff and J. J. Lingane, Polarography, 2 ed., Interscience, N. Y., London, Vol. II (1952).
- [11] E. Scrocco and F. Cappellina, Boll. sci. fac. chim. ind. Bologna 12, 101 (1954); C. A. 49, 8003 (1955).
- [12] O. A. Reutov, Theoretical Problems of Organic Chemistry, publ. Moscow State Univ. (1956). *

Received January 24, 1958

* In Russian.

** Original Russian pagination. See. C.B. Translation.

POLAROGRAPHIC STUDY OF ANTHRAQUINONE COMPOUNDS AND THEIR TETRA- AND OCTAHYDRO DERIVATIVES

V. E. Ditsent

Several papers devoted to the polarographic study of 9,10-anthraquinone and its sulfo and hydroxy derivatives exist in the literature [1-5]. However, the data on a polarographic study of alkylanthraquinones and their tetra- and octahydro derivatives are not to be found in the literature.

The results of a polarographic study of some compounds of the anthraquinone series and their tetra- and octahydro derivatives are given in this paper.

EXPERIMENTAL

The following substances were taken for the study: 9,10-anthraquinone (pure, TU-2816-51), 2-methyl-9,10-anthraquinone - light yellow needles with m. p. 173°, prepared by the condensation of phthalic anhydride with toluene in the presence of aluminum chloride with the subsequent cyclization of toluene-o-benzoic acid with the aid of concentrated sulfuric acid [6].

2-Ethyl-9,10-anthraquinone and 2-isopropyl-9,10-anthraquinone were synthesized in a similar manner from phthalic anhydride and ethylbenzene and isopropylbenzene. The products were light yellow crystals and had m. p. 108° and 56°, respectively. Tetra- and octahydro derivatives were prepared by hydrogenation of alcoholic solutions of the anthraquinones in the presence of Raney nickel. The resulting tetra- and octahydroanthrahydroquinones were oxidized by oxygen to the corresponding quinones and, after recrystallization from acetone, had the properties shown in Table 1.

TABLE 1

Name of derivative of 9,10-anthraquinone	M. p.	Found (%)		Calculated (%)	
		C	H	C	H
Tetrahydro-	158°	79.7	5.9	79.3	5.7
Tetrahydro-2-methyl-	171	80.0	6.4	79.6	6.2
Tetrahydro-2-ethyl-	169	80.4	6.7	80.0	6.7
Tetrahydro-2-isopropyl-	155	80.4	7.6	80.3	7.2
Octahydro-	184	78.5	7.7	78.3	7.4
Octahydro-2-methyl-	136	78.0	7.4	78.0	7.8
Octahydro-2-ethyl-	104	79.3	8.4	78.8	8.2
Octahydro-2-isopropyl-	111	80.0	8.2	80.6	8.6

The polarographic study of anthraquinone compounds was run on a photorecording polarograph.* The electrolytic cell was a hermetically closed electrolysis vessel provided with the thermostatic jacket. The determinations were run at 25°.

* Polarograph constructed by "Giredmet", Odessa, Model No. 8.

The capillary constant in the medium of 50% dioxane in a solution of 0.1 N lithium chloride was $m^2 s^{1/6} = 1.803$. A saturated calomel halfcell served as the anode. The current strength was measured with a mirror galvanometer having the sensitivity of $1.6 \cdot 10^{-9}$ amp. A mixture of dioxane and water (1 : 1) was used as the solvent for the quinones. The polarography was run with the background of unbuffered (0.1 N LiCl, HCl and NaOH) and buffered solutions (universal buffer mixtures [7]). The pH values of the buffered solutions were controlled by means of a glass electrode.

TABLE 2

9,10Anthraquinones and their derivatives	Background							
	HCl		LiCl		NaOH			
	constant of the diffusion current	halfwave potential (-V)	constant of the diffusion current	halfwave potential (-V)	constant of the diffusion current	halfwave potential (-V)	constant of the diffusion current	halfwave potential (-V)
					first wave		second wave	
9,10-Anthraquinone	2.00	0.17	2.20	0.72	0.89	0.69	0.89	0.85
2-Methyl-	1.99	0.18	2.16	0.74	0.88	0.69	0.89	0.86
2-Ethyl-	1.85	0.18	1.94	0.73	0.88	0.69	0.87	0.87
2-Isopropyl-	1.80	0.19	1.89	0.74	0.81	0.71	0.81	0.88
Tetrahydro-			1.93	0.58	0.72	0.57	0.72	0.71
Tetrahydro-2-methyl-			1.86	0.59	0.70	0.58	0.70	0.72
Tetrahydro-2-ethyl-			1.89	0.58	0.72	0.58	0.72	0.73
Tetrahydro-2-isopropyl			1.91	0.60	0.68	0.57	0.68	0.72
Octahydro-			1.79	0.49	0.72	0.50	0.72	0.62
Octahydro-2-methyl-			1.78	0.50	0.69	0.50	0.69	0.62
Octahydro-2-ethyl			1.78	0.48	0.72	0.49	0.72	0.60
Octahydro-2-isopropyl			1.70	0.51	0.69	0.51	0.69	0.61

Study in unbuffered solutions. The values of the constants of the diffusion current and the halfwave potentials for the compounds which were studied are given in Table 2. 9,10-Anthraquinone and its alkyl substituted derivatives were reduced in acid, neutral and alkaline media and gave clearly defined polarographic waves. The waves were single wave in acid and neutral media, and double waves in alkaline media; here, the heights of individual waves were equal in the last instance. The typical polarograms are shown in Fig. 1. Similar waves were obtained in neutral and alkaline media for tetra- and octahydro derivatives. The half-wave potentials of these compounds could not be determined in an acid medium since they were strongly shifted toward positive emf values and coincided with the potential of anodic oxidation of mercury.

A direct proportionality exists between the strength of the diffusion current and the concentration of the compounds being studied in the range of concentrations from 0.02 to 1 millimole/liter.

As it is evident from the data in Table 2, introduction of substituents into the molecule of anthraquinone and its tetra- and octahydro derivatives does not alter the halfwave potentials of these substances. It is interesting to note in this connection that, according to the literature data, introduction of substituents (for example CH_3 , CH_3COO) into the molecule of benzoquinone [8] and naphthoquinone [9] noticeably shifts the halfwave potentials of these compounds toward the negative values. The halfwave potentials of the tetrahydro derivatives are shifted toward the positive values by 0.12-0.15 v, and those of octahydro derivatives by 0.20-0.23 v, in comparison with the halfwave potentials of the original anthraquinone compounds (Table 2).

Introduction of substituents (CH_3 , C_2H_5 , C_3H_7) into the anthraquinone molecule decreases somewhat (from 2.20 to 1.89) the values of the diffusion current constant.

Study in buffer solutions. The halfwave potentials of the compounds being studied depend strongly on the hydrogen ion concentration in the solution. In passing from an acid medium to a neutral or alkaline one the halfwave potentials are shifted toward the negative values by 0.55-0.70 v. For a more detailed study of

the dependence of halfwave potentials of the anthraquinone compounds on the hydrogen ion concentration, we ran polarography of these compounds in buffer solutions with pH from 1.85 to 11.45. A typical graph of the dependence of $E_{1/2}$ on pH is shown in Fig. 2. The $E_{1/2}$ shifts in the direction of negative values with increase of pH from 2 to 9, and the average shift of $E_{1/2}$ per pH unit is 0.06 v.

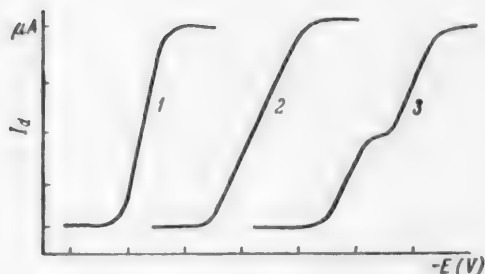


Fig. 1. Polarogram of 2-ethyl-9,10-anthraquinone in the medium of 50% dioxane. 1) with background of 0.1 N HCl; 2) with background of 0.1 N LiCl; 3) with background of 0.1 N NaOH.

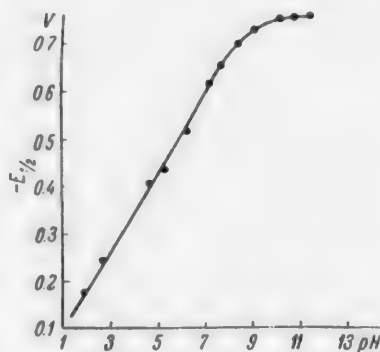


Fig. 2. Effect of pH of buffer solutions on halfwave potential of 2-ethyl-9,10-anthraquinone.

Reduction of anthraquinone compounds on a dropping mercury electrode is a reversible process [10, 11]; therefore, it is possible to calculate the number of electrons (n) participating in the reduction of one molecule depending on the pH of the solution, by using the polarographic wave equation [12].

Some of the graphs of the dependence of $\lg[1/(I_d - I)] - E$ are given in Figs. 3 and 4.

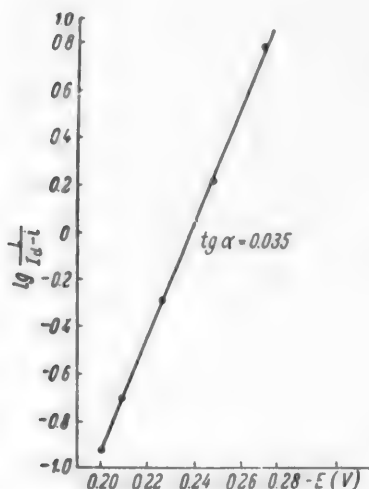


Fig. 3. Dependence of $\lg[1/(I_d - I)]$ on the potential of dropping mercury electrode (relative to saturated calomel electrode) for 2-ethyl-9,10-anthraquinone in the medium of 50% dioxane in buffer solution with pH 2.45.

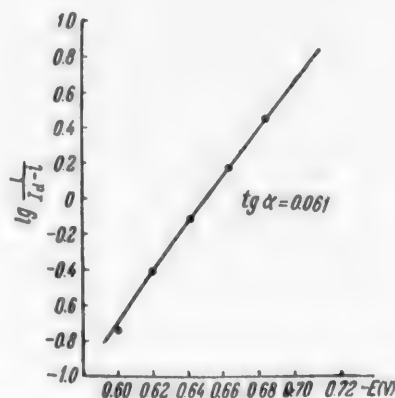
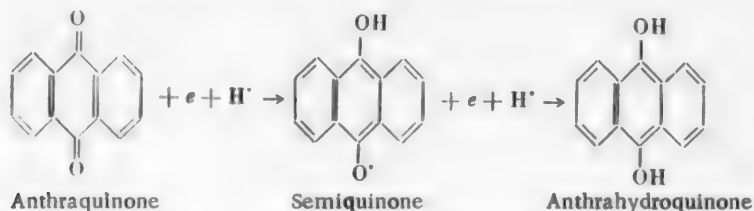


Fig. 4. Dependence of $\lg[1/(I_d - I)]$ on the potential of dropping mercury electrode (relative to saturated calomel electrode) for the wave of 2-ethyl-9,10-anthraquinone in a medium of 50% dioxane in buffer solution with pH 10.05.

The calculation made by us indicated that the value of \bar{n} depends on the pH of the solution: at pH < 4, $\bar{n} = 2$, for pH > 4, $\bar{n} = 1$.

The wave heights for the same compound are equal over the interval of pH of the buffer solutions studied by us. This indicates that all the waves correspond to one and the same electrochemical process - reduction of anthraquinone to anthrahydroquinone with participation of two electrons. The differences in the values of \bar{n} may be explained by the different mechanisms of addition of the electrons to the molecule being reduced. In the first case (pH < 4) the electrons add to the molecule simultaneously which fact is fixed by the polarographic wave whose slope corresponds to $\bar{n} = 2$, while in the second case (pH > 4) the electrons add to the molecule in succession, in two stages with formation of a semiquinone as an intermediate compound [13].



A single wave with the slope corresponding to a one-electron process is obtained on the polarogram, owing to the closeness of the values of the halfwave potentials of the first and the second stages of reduction of anthraquinone. The difference in the values of $E_{1/2}$ for the two stages of reduction increases so much with the rise of pH to 13 (0.1 N sodium hydroxide solution) that the waves cease to be superimposed on each other and a two-step curve with equal wave heights (Fig. 1) is obtained on the polarogram. The data obtained in this work agree with the observations made by Furman and Stone [2], who established that the slope of the polarographic waves of sulfo derivatives of anthraquinone in buffer solutions from pH 4 to pH 8 is close to that for the single electron reduction process.

SUMMARY

1. The reduction of twelve compounds of anthraquinone series was studied on the dropping mercury electrode.
2. It was shown that the introduction of substituents (CH_3 , C_2H_5 , C_3H_7) into the anthraquinone molecule and those of its hydro derivatives does not affect the halfwave potential. Hydrogenation of the side rings of anthraquinone compounds leads to a shift of the halfwave potentials toward the positive values by 0.12-0.15 v for tetrahydro derivatives and by 0.20-0.23 v for octahydro derivatives.
3. It was shown that the mechanism of reduction of the compounds studied by us depends on the pH of the solution: at pH < 4 the reduction is a single stage process, at pH > 4 the reduction proceeds in two stages with formation of a semiquinone in the first stage of reduction.

LITERATURE CITED

- [1] H. Adkins and R. Cox, J. Am. Chem. Soc. 60, 1115 (1938).
- [2] N. Furman and K. Stone, J. Am. Chem. Soc. 70, 3055 (1948).
- [3] R. Gill and H. Stonehill, J. Chem. Soc., 1952, 1845.
- [4] L. Wiles, J. Chem. Soc., 1952, 1358.
- [5] Yu. I. Vainshtein, Plant Laboratory (USSR) 15, 411 (1949).
- [6] Syntheses of Organic Preparations (USSR ed.) Coll., Vol. 1, 253, 389 (1949).
- [7] H. Britton, Hydrogen Ions, Theoret. Chem. Press (1936).*
- [8] A. G. Stromberg and L. M. Reinus, J. Gen. Chem. 16, 1431 (1946).

* Russian translation.

- [9] I. F. Vladimirov, Dissertation, Sverdlovsk (1952).*
- [10] O. Muller and J. Baumberger, Trans. Am. Electroch. Soc. 71, 169, 181 (1937).
- [11] R. Edsberg, D. Etchlin, and I. Garis, Anal. Chem. 25, 798 (1953).
- [12] I. M. Kolthoff and J. J. Lingane, Polarography, State Chem. Press, p. 150 (1948).**
- [13] S. Glasstone, Introduction to Electrochemistry, Foreign Press, 385 (1951).**

Received January 28, 1958

* In Russian.

** Russian translation.

PHYSICOCHEMICAL STUDY OF THE REACTION OF ZIRCONIUM
CHLORIDE WITH ESTERS OF MONOBASIC ACIDS. III.

O. A. Osipov and Yu. B. Kletenik

Rostov-on-Don State University

It was shown in one of our previous papers devoted to the study of the reaction of zirconium tetrachloride with esters of monobasic carboxylic acids [1] that complexes with the composition $ZrCl_4 \cdot 2E$ may exist in benzene solution and in the crystalline state, these complexes evidently containing zirconium with the coordination number of 5, in addition to the complexes with composition $ZrCl_4 \cdot 2E$, which are known in the literature [2] and in which zirconium displays the coordination number of 6. According to Sidgwick's data [3], zirconium is capable of forming complex compounds not only with coordination numbers 5 and 6, but also 7 and 8. The problem of the reaction of zirconium tetrachloride with the third, fourth, and more molecules of esters has not been raised in the literature known to us. At the same time, a study of this reaction may clarify whether or not zirconium in the complexes of the tetrachloride with oxygen-containing organic addends is capable of displaying a coordination number greater than six.

The ability of halides of metals of the Fourth group of the periodic system to form molecular compounds with oxygen-containing organic addends has been studied most thoroughly for tin and titanium tetrachlorides [4, 5]. A physicochemical study of systems formed by $SnCl_4$ and $TiCl_4$ with esters indicates the existence, in the liquid phase, of complexes with the compositions $MCl_4 \cdot E$ and $MCl_4 \cdot 2E$. No indications have been discovered about the existence of compounds containing more than two molecules of an ester per one molecule of MCl_4 . It is true that in a number of cases it has been possible to isolate complexes with $SnCl_4$ having the 1 : 3 and even 1 : 4 compositions, but the addition of the third and the fourth molecules in such complexes has, evidently, the character of a dipole-dipole interaction [6-8].

A study of the reaction of zirconium tetrachloride with esters of monobasic acids by the techniques of physicochemical analysis of the binary systems of $ZrCl_4$ -ester is connected with the real difficulty in that zirconium chloride, in contrast to $SnCl_4$ and $TiCl_4$, melts only under pressure and at a high temperature. According to our observations, the melting point of mixtures of zirconium chloride with a small amount of an ester (we took ethyl formate, acetate, or butyrate) lies much higher than the temperature at which the mixtures begin to form tars. Even with the molar proportion of the components of 1 : 1 and 1 : 2, the mixtures melt with considerable tar formation; once molten, they, as a rule, do not crystallize on being cooled.

The goal of the present study was the examination of the reaction of complexes of composition $ZrCl_4 \cdot 2E$ with the third molecule of an ester in benzene. It was necessary for the solution of this problem to have some definite data on the molecular state of the complexes with composition $ZrCl_4 \cdot E$ and $ZrCl_4 \cdot 2E$ in benzene.

The complex character of the dependence of polarization of the complexes with composition $ZrCl_4 \cdot 2E$ on concentration, discovered by us previously [9], was explained by us by a superposition of the processes of association of the polar complexes and their dissociation into the original components. In order to confirm the correctness of this supposition we ran, in the present study, a cryoscopic examination of some of these complexes.

The technique of dielectric (measurements of dielectric constant) and cryoscopic studies, as well as the constants of the reagents used for the work, have been presented previously [9-11].

The data on cryoscopy of benzene solutions of complexes $\text{ZrCl}_4 \cdot 2\text{HCOOC}_2\text{H}_5$, $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ and $\text{ZrCl}_4 \cdot 2\text{C}_3\text{H}_7\text{COOC}_2\text{H}_5$ are given in Tables 1-3* and on Fig. 1.

TABLE 1

Complex $\text{ZrCl}_4 \cdot 2\text{HCOOC}_2\text{H}_5$ in C_6H_6
($M_{\text{theor}} = 381$)

c	Δt°	M_{exp}	$\frac{M_{\text{exp}}}{M_{\text{theor}}}$
0.01631	0.575	716	1.88
0.01280	0.501	644	1.69
0.00915	0.399	575	1.51
0.00621	0.309	504	1.32
0.00379	0.210	450	1.18
0.00215	0.131	409	1.07
0.00151	0.100	377	0.99

TABLE 2

Complex $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ in C_6H_6
($M_{\text{theor}} = 409$)

c	Δt°	M_{exp}	$\frac{M_{\text{exp}}}{M_{\text{theor}}}$
0.01942	0.743	711	1.74
0.01458	0.628	631	1.54
0.01009	0.482	566	1.38
0.00655	0.350	504	1.23
0.00421	0.246	459	1.12
0.00241	0.158	409	1.00
0.00180	0.128	377	0.92

A comparison of the results (Tables 1-3) with the data on polarization confirms the correctness of the suppositions made previously concerning the reasons for the complex character of the dependence of polarization of the complexes studied by us on the concentration. In reality, the association of the molecules of the complex should lead to the increase of the apparent molecular weight. With dilution of the system, the degree of association should decrease and the limiting case at $c \rightarrow 0$, the ratio of $M_{\text{exp}}/M_{\text{theor}}$ should become

equal to unity. The decrease of this ratio to magnitudes considerably smaller than unity indicates the decomposition of the complex into its components. The possibility of a noticeable electrolytic dissociation of these complexes at concentrations below 0.01 mole fraction must be excluded since their benzene solutions are practically nonconducting at such concentrations (electroconductivity of the order of 10^{-6} – 10^{-7} $\text{cm}^{-1}\text{ohm}^{-1}$ appears only at concentrations above 0.01 mole fraction).

TABLE 3

Complex $\text{ZrCl}_4 \cdot 2\text{C}_3\text{H}_7\text{COOC}_2\text{H}_5$ in C_6H_6
($M_{\text{theor}} = 465$)

c	Δt°	M_{exp}	$\frac{M_{\text{exp}}}{M_{\text{theor}}}$
0.01788	0.982	563	1.21
0.01290	0.768	516	1.11
0.00945	0.599	484	1.04
0.00628	0.421	456	0.98
0.00335	0.252	405	0.87
0.00221	0.190	354	0.76

We obtained a polarization curve, for the complex of zirconium tetrachloride with ethyl formate, which descended steeply with the rise of concentration. This corresponds, on the cryoscopic curve (Fig. 1), to a rapid growth of the ratio $M_{\text{exp}}/M_{\text{theor}}$. For the next two complexes formed by zirconium tetrachloride with ethyl acetate and ethyl butyrate the cryoscopic curves rise consid-

erably more slowly with the rise of the concentration. A compensation of the processes of association and decomposition of the complexes (equality of the ratio $M_{\text{exp}}/M_{\text{theor}}$ to unity) occurs for complexes with ethyl formate, ethyl acetate, and ethyl butyrate at concentrations of 0.00160, 0.00241, and 0.00720 mole fractions, respectively. Thus, in the series formate-acetate-butyrate there are observed the decrease of the tendency of the complex toward association and a rise of the tendency of it to decompose into the components.

It was established by us previously [1] that complexes with the composition $\text{ZrCl}_4 \cdot E$ do not display a

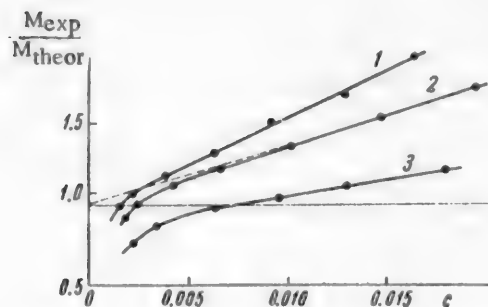
* Concentrations in Tables 1-3 are given in mole fractions for convenience of comparison with the data on dielectric polarization of the same complexes [9].

noticeable tendency to decompose into their components in benzene. The same conclusion is reached by a consideration based on the fact of the insolubility of zirconium chloride in benzene [1, 12]. Actually, in case of a noticeable dissociation according to the scheme $\text{ZrCl}_4 \cdot \text{E} \rightleftharpoons \text{ZrCl}_4 + \text{E}$, zirconium chloride should precipitate and the equilibrium should shift to the right, which is not observed in fact. Therefore, we may regard the scheme of the decomposition of a complex of composition $\text{ZrCl}_4 \cdot 2\text{E}$ in benzene as a cleavage of but one molecule of the ester:



Such a dissociation scheme agrees well with the values of the heats of addition of molecules of an ester to zirconium chloride. According to our preliminary data, the heat of addition of the first molecule of ethyl acetate to zirconium chloride is about 18 kilocal/mole, and that of the second molecule - only 3 kilocal/mole.

A similar dissociation scheme has been proposed by Ulich, Hertel and Nespital [13] for complexes of SnCl_4 with esters in benzene.



Cryoscopy of solutions of complexes in benzene.
1) $\text{ZrCl}_4 \cdot 2\text{HCOOC}_2\text{H}_5$; 2) $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$;
3) $\text{ZrCl}_4 \cdot 2\text{C}_2\text{H}_5\text{COOC}_2\text{H}_5$.

The fact of the existence of mixed complexes of composition $\text{ZrCl}_4 \cdot \text{E} \cdot \text{C}_6\text{H}_6$, established by us previously [1], led us to the supposition that benzene takes an active part in the process of dissociation of the complexes of composition $\text{ZrCl}_4 \cdot 2\text{E}$, by reacting with the complex of composition $\text{ZrCl}_4 \cdot \text{E}$ formed as the result of the dissociation and by forming a mixed complex, thereby aiding the dissociation. It should be expected in this connection that the degree of dissociation of complexes of composition $\text{ZrCl}_4 \cdot 2\text{E}$ in other nonpolar solvents would be considerably smaller. The insolubility of such complexes in such solvents as carbon tetrachloride, hexane and heptane, presented us from checking the correctness of such a supposition.

The results of measurements of molar polarization of the complex of zirconium chloride with ethyl formate in benzene solutions, containing zirconium chloride and the ester in 1 : 3 molar proportion, are given in Table 4. It was presupposed during the calculation of the polarization of the complex that only two molecules of the ester enter its composition.

The polarization of the third, free molecule of ethyl formate was taken as equal to 96.

TABLE 4

Polarization of the Complex of ZrCl_4 with Ethyl Formate in C_6H_6

c_1	c_2	ϵ_{20}	d_1^{20}	P (cm ³)
0.01411	0.01411	3.556	0.9057	1027
0.01079	0.01079	3.291	0.8995	1107
0.00849	0.00849	3.058	0.8944	1168
0.00556	0.00556	2.815	0.8893	1230

Note. Symbols c_1 and c_2 in Table 4 denote the mole fractions of the complex of composition $\text{ZrCl}_4 \cdot 2\text{E}$ and of the free ester.

This value was secured by us by measurement of the polarization of ethyl formate in benzene and agrees well with the literature data [14, 15]. The value of $96 \cdot c_2$, i.e., the fraction of this polarization which belongs to free ethyl formate, was subtracted from the molar polarization of the solution. The polarization of the complex was measured at such concentrations at which its decomposition into the components was quite insignificant according to the cryoscopic data (Table 1).

A comparison of the above data on polarization with those obtained previously [9] for the magnitudes of polarization of the complex with composition $\text{ZrCl}_4 \cdot 2\text{HCOOC}_2\text{H}_5$ without the third, excess molecule of the ester leads to the conclusion that the third molecule of ethyl formate does not influence the polarity of the complex within the limits of experimental error.

The data on polarization of the complex of zirconium tetrachloride with ethyl acetate in benzene solutions which contain zirconium chloride and the ester in molar proportions 1 : 3, 1 : 5 and 1 : 7 are given in Table 5. It was again supposed during the calculation of the polarization that only two molecules of the ester enter the composition of the complex and the value of $94 \cdot c_2$, i.e., the fraction of this polarization attributable to free ethyl acetate,* was subtracted from the molar polarization of the solution.

TABLE 5

Molar Polarization of the Complex of ZrCl_4 with Ethyl Acetate in Benzene

c_1	c_2	ϵ_{90}	d_{90}	P (cm ³)
Molar ratio of ZrCl_4 to ethyl acetate 1 : 3				
0.00621	0.00621	2.829	0.8907	1148
0.00402	0.00402	2.623	0.8865	1139
0.00264	0.00264	2.503	0.8838	1135
0.00200	0.00200	2.448	0.8825	1124
Molar ratio of ZrCl_4 to ethyl acetate 1 : 5				
0.00614	0.01842	2.888	0.8906	1144
0.00419	0.01257	2.684	0.8868	1148
0.00281	0.00843	2.547	0.8841	1147
0.00199	0.00597	2.470	0.8825	1151
Molar ratio of ZrCl_4 to ethyl acetate 1 : 7				
0.00681	0.03405	3.041	0.8919	1144
0.00403	0.02015	2.711	0.8865	1153
0.00265	0.01325	2.559	0.8838	1154
0.00200	0.01000	2.490	0.8825	1152

It is possible to conclude in comparing these data on polarization of the complex $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ with excess ester with the values obtained previously for the polarization of the same complex, but without excess ester [9], that the addition of excess ethyl acetate above that needed for the formation of the complex with composition $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ leads to but a small rise of polarization which is easily explained by the repression of dissociation of the complex. At the concentration of the complex of the order of 0.006 mole fraction, i.e., when the dissociation into components becomes insignificant, judging by the cryoscopic data (Table 2), the polarization of the complex without and with the excess ethyl acetate is the same within the limits of experimental error. Thus, even in the case of ethyl acetate a noticeable interaction of zirconium tetrachloride with the third molecule of the ester is not to be observed.

A cryoscopic study of the interaction of the complex with composition $\text{ZrCl}_4 \cdot 2\text{E}$ with the third molecule

* The polarization of excess ethyl acetate was taken as being equal to 94. This value, like the one for ethyl formate, was secured by a measurement of polarization of ethyl acetate in benzene and agreed well with the literature data [14-16]. We disregarded the small change of polarization of free ethyl acetate with concentration at such relatively low magnitudes of the latter.

of the ester consisted of the following. We determined the freezing point of a benzene solution of the complex $ZrCl_4 \cdot 2E$ of a known concentration(c) expressed in mole fractions. Then, to this solution we added the ester in molar amount equal to the number of moles of the complex contained in the solution, after which we again determined the freezing point of the solution. The resulting value of the temperature depression Δt_{exp}° was compared with the value of the temperature depression which should have been expected under the conditions of an absence of interaction of the added ester with the original complex. This value - Δt_{theor}° - was found by calculation from the usual cryoscopic formula.

The results of such a cryoscopic study are given in Table 6 for benzene solutions of complexes of $ZrCl_4$ with methyl formate, ethyl formate, and ethyl acetate. These data indicate that the complexes with composition $ZrCl_4 \cdot 2E$ do not react with the third molecule of the ester. The small deviations of the ratio $\Delta t_{exp}^\circ / \Delta t_{theor}^\circ$ from unity (all in the direction of a decrease) can be readily explained by deviation of the solution from ideality with the concentrations used and by the suppression of dissociation of the complexes of composition $ZrCl_4 \cdot 2E$. The latter is especially true for the third solution with ethyl acetate. A noticeable interaction with the third molecule could not be detected even for the case of methyl formate which has the smallest molecular dimensions among all the possible esters and thus one that creates the least steric hindrance to the formation of complexes.

If one considers that the increase of the dimensions of the acid residue of the ester leads to the lessened bond strength of even the second molecule of the ester with zirconium chloride (this follows from the data of our previous work [9] and from the results of the cryoscopic studies cited above), we have grounds to suppose that zirconium chloride does not react with more than two molecules of an ester in benzene, even with the other esters of monobasic acids.

TABLE 6
Cryoscopy of Complexes with Excess Ester

Composition of the complex	"	Δt_{theor}°	Δt_{exp}°	$\frac{\Delta t_{exp}^\circ}{\Delta t_{theor}^\circ}$
$ZrCl_4 \cdot 2HCOOCH_3$	0.01081	0.714	0.677	0.95
	0.00930	0.612	0.588	0.96
	0.00670	0.441	0.423	0.96
$ZrCl_4 \cdot 2HCOOC_2H_5$	0.01281	0.845	0.802	0.95
	0.00915	0.603	0.567	0.94
	0.00621	0.408	0.388	0.95
$ZrCl_4 \cdot 2CH_3COOC_2H_5$	0.01460	0.967	0.928	0.96
	0.00655	0.430	0.400	0.93
	0.00421	0.276	0.240	0.87

In comparing the data for the complex of zirconium chloride with ethyl acetate with different excesses of the latter (Table 5) we note that the addition of the sixth molecule of the ester no longer affects the value of P , which indicates the almost complete suppression of dissociation of the complex. The value of $P = 1150 \text{ cm}^3$ may be regarded as the polarization of the complex proper with the composition $ZrCl_4 \cdot 2CH_3COOC_2H_5$. Knowing this value and the value of polarization of the complex at a given, small concentration of the latter (P_c), as well as the value of polarization of the complex at infinite dilution, i.e., with complete cleavage of one ester molecule (P_∞), it is possible to calculate the degree and the constant of dissociation of the complex. However, it is difficult to determine the value of P_∞ directly and experimentally owing to the necessity of studying some extremely dilute solutions.

Earlier we had determined the molar polarization of the complex $ZrCl_4 \cdot CH_3COOC_2H_5$ which turned out to be equal to 384 cm^3 [1]. If one considers that the infinite dilution of the solution of the complex $ZrCl_4 \cdot 2CH_3COOC_2H_5$ one molecule of the ester is completely cleaved, then the polarization of the complex

should become equal to 384 cm^3 . However, in the calculation of P_c for the complex $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ we did not consider the dissociation and regarded that the molar polarization of the solution, P_{soln} , consisted of two parts: $P_{\text{soln}} = P_{\text{benz}} \cdot c_{\text{benz}} + P_{\text{compl}} \cdot c_{\text{compl}}$, while in reality part of the ester is cleaved and P_{soln} consists of three parts: $P_{\text{soln}} = P_{\text{benz}} \cdot c_{\text{benz}} + P_{\text{compl}} \cdot c_{\text{compl}} + P_{\text{ethyl ac}} \cdot c_{\text{ethyl ac}}$. If we had possessed some sufficiently accurate data for very dilute solutions and if we calculated the values of P_c according to the first equation, we would have obtained a value greater than 384 cm^3 by some 67 units, i.e., by the difference of molar polarizations of ethyl acetate in benzene and benzene itself. Thus, the most dependable value of P_{∞} for the complex $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ is $384 + 67 = 451 \text{ cm}^3$.

Knowing the molar polarization of the complex $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ itself ($P_{\text{compl}} = 1150$), its polarization with the total cleavage of one molecule of the ester ($P_{\infty} = 451$) and the observed values of polarization of the complex in solutions of molar concentration "c" (P_c), we can, to the first approximation, calculate the degree of dissociation of the complex (α) and the constant of its dissociation (K) by the equations:

$$\alpha = \frac{P_{\text{compl}} - P_c}{P_{\text{compl}} - P_{\infty}} \quad \text{and} \quad K = \frac{\alpha^2 c}{1 - \alpha}.$$

The results of such a calculation are given in Table 7 for two solutions, the magnitudes of P_c for which were given in our previous paper [9].

TABLE 7

Degree of the Dissociation Constant of Solutions of $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ in Benzene

c	P_c	α	$K \cdot 10^4$
0.0528	1103	0.067	2.6
0.0359	1083	0.096	3.5

We also made the calculation of the degree of the constant of dissociation of the complex $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ on the basis of the cryoscopic data, considering that with the complete cleavage of one molecule of the ester, (i.e., with $c \rightarrow 0$) the ratio $M_{\text{exp}}/M_{\text{theor}} = 0.5$ and that in the absence of dissociation the cryoscopic curve would go in the direction indicated in Fig. 1 by the dotted line. For solution 6 (Table 2) we obtained $\alpha = 0.152$ and $K = 6.2 \cdot 10^{-4}$. Some deviations in the values of the dissociation constant of the complex may be explained by the neglect of dimerization of the complex $\text{ZrCl}_4 \cdot \text{CH}_3\text{COOC}_2\text{H}_5$ which forms as a result of dissociation of the original complex, as well as by the experimental errors which are inevitable for such dilute solutions.

SUMMARY

1. Solutions of complexes $\text{ZrCl}_4 \cdot 2\text{HCOOC}_2\text{H}_5$, $\text{ZrCl}_4 \cdot 2\text{CH}_3\text{COOC}_2\text{H}_5$ and $\text{ZrCl}_4 \cdot 2\text{C}_3\text{H}_7\text{COOC}_2\text{H}_5$ were studied cryoscopically in benzene. It was established that complexes of this composition dissociate noticeably into their components, while in the series formate-acetate-butyrate the tendency toward dissociation increases. The scheme of this dissociation was suggested.

2. It was established by the method of cryoscopy and dielectric permeability that zirconium chloride in benzene reacts with no more than two molecules of an ester.

* These discussions do not represent anything principally new [17, 18]. We are led to cite them here only by the certain peculiarity of the particular case - cleavage of but one of two ester molecules which enter the composition of the complex.

3. The dissociation constant of the complex was calculated from the data on polarization and cryoscopy, whereupon both methods gave a value of the constant of the same order of magnitude (about $5 \cdot 10^{-4}$).

LITERATURE CITED

- [1] Yu. B. Kletenik, O. A. Osipov, and E. E. Kravtsov, *J. Gen. Chem.* 29, 12 (1959).*
- [2] A. Rosenheim and J. Hertzmann, *Ber.* 40, 810 (1907).
- [3] N. V. Sidgwick, *Electronic Theory of Valence*, London (1932).
- [4] N. S. Kurnakov, *Collection of Selected Works*, vol. 1 (1938).**
- [5] O. A. Osipov and V. Suchkov, *J. Gen. Chem.* 22, 1132 (1952);* Yu. A. Lysenko and O. A. Osipov, *J. Gen. Chem.* 24, 53 (1954);* O. A. Osipov and Yu. A. Lysenko, *J. Gen. Chem.* 25, 249 (1955).*
- [6] M. I. Usanovich and E. I. Kalabanovskaya, *J. Gen. Chem.* 17, 1233 (1947); *Bull. of Platinum Section, Inst. Gen. and Inorg. Chem. Acad. Sci. USSR*, No. 21, 228 (1948).
- [7] T. Sumarokova and E. Yarmukhamedova, *J. Gen. Chem.* 26, 3295 (1956).*
- [8] O. A. Osipov, G. S. Samofalova, and E. I. Glushko, *J. Gen. Chem.* 27, 1428 (1957).*
- [9] O. A. Osipov and Yu. B. Kletenik, *J. Gen. Chem.* 27, 2921 (1957).*
- [10] O. A. Osipov and A. D. Semenov, *J. Gen. Chem.* 25, 2059 (1955).*
- [11] O. A. Osipov, *J. Gen. Chem.* 26, 322 (1956).*
- [12] W. B. Blumenthal, *Ind. Eng. Ch.* 46, 528 (1954).
- [13] H. Ulich, E. Hertel, and W. Nespital, *Z. phys. Ch. B.* 17, 21 (1932).
- [14] C. P. Smyth and W. Walls, *J. Am. Chem. Soc.* 53, 527 (1931).
- [15] J. Sakurada and M. Taniguchi, *Bull. Inst. Phys.-Chem. Res. (Tokyo)*, 12, 224 (1933).
- [16] A. E. van Arkel and J. L. Snock, *Phys. Z.* 35, 187 (1934).
- [17] A. V. Few and J. W. Smyth, *J. Chem. Soc.*, 1949, 2781.
- [18] I. A. Sheka, *Dissertation*, Kiev (1952).**

Received January 23, 1958

*Original Russian pagination. See C.B. Translation.

**In Russian.

PHYSICOCHEMICAL STUDY OF THE STRUCTURE AND THE PROPERTIES OF THE OXYGEN COMPOUNDS OF NICKEL

D. P. Bogatskii and I. A. Mineeva

Institute of General and Inorganic Chemistry of the Academy of Sciences, USSR, and the Moscow Institute of Nonferrous Metals

The conditions have been worked out for the preparation of pure anhydrous nickel oxides, which correspond accurately to the appropriate chemical formulas, and for their solid solutions [1], which were subjected to a detailed study by the various methods of physicochemical analysis [2] for the investigation of the existing oxygen compounds of nickel, their structure, and properties.

In order to insure the high degree of accuracy and sensitivity, the thermographic study* of the isobaric processes of thermal dissociation of nickel oxides and of their solid solutions was run by the method of differential thermal analysis with automatic recording of the heating and cooling curves by means of N. S. Kurnakov's auto-recording pyrometer, with different sensitivities of the differential thermocouples at various temperatures.

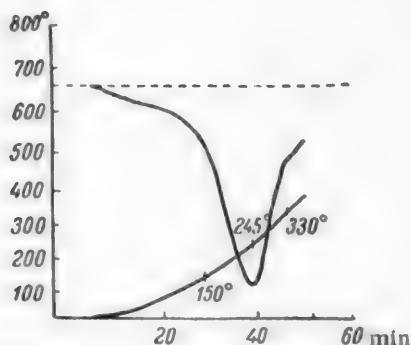


Fig. 1. Dissociation of nickel dioxide, prepared by dehydration of the hydrate under high pressure.

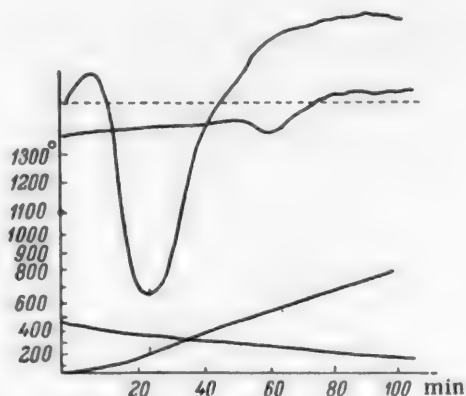


Fig. 2. Dissociation of nickel dioxide, prepared by dehydration of the hydrate under vacuum.

The processes of thermal dissociation of the following oxides and their solid solutions were subjected to the study:

- a) nickel dioxide, prepared by dehydration of its hydrate under high pressure with heating (Fig. 1) and under vacuum in the cold in the presence of water absorbents (Fig. 2);

* The thermographic studies were made in L. G. Berg's laboratory at the Institute of General and Inorganic Chemistry of the Academy of Sciences, USSR.

b) nickel dioxide, prepared by dehydration of its hydrate under vacuum and one that was partly dissociated in the process of prolonged hold (to constant weight) in air at 50° in the presence of water absorbents (Fig. 3);

c) solid solutions of nickel dioxide and oxide, prepared by heating to constant weight of a specimen of nickel dioxide in air at 100 and 150° (Figs. 4 and 5);

d) solid solution of nickel dioxide and oxide, prepared by prolonged heating to constant weight of nickel nitrate in air at 220-230° (Fig. 6);

e) nickel oxide prepared by heating in air to constant weight of a specimen of nickel dioxide at 200° (Fig. 7) and nickel nitrate at 250° (Fig. 8);

f) solid solutions of nickel oxide and nickelous oxide prepared by heating in air to constant weight of a specimen of nickel dioxide at 250° (Fig. 9) and nickel oxide at 300°, 400°, and 600° (Figs. 10 and 11);

g) nickelous oxide prepared by prolonged heating of nickel oxide and solid solutions of nickel oxide and nickelous oxide to constant weight in air at 1150° (Fig. 12).

Nickel dioxide (NiO_2) is the least stable of all the oxygen compounds of nickel that were studied and has a rather high dissociation pressure, as it follows from the differential thermograms shown. The beginning of the dissociation process of nickel dioxide during its heating in air atmosphere is clearly shown thermographically at even 70-80°. During the process of a prolonged isothermal hold, the process of dissociation of nickel dioxide in

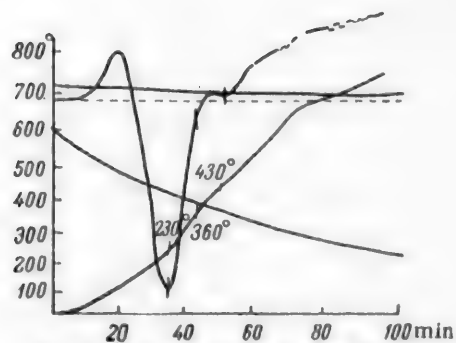


Fig. 3. Dissociation of nickel dioxide kept in air at 50°.

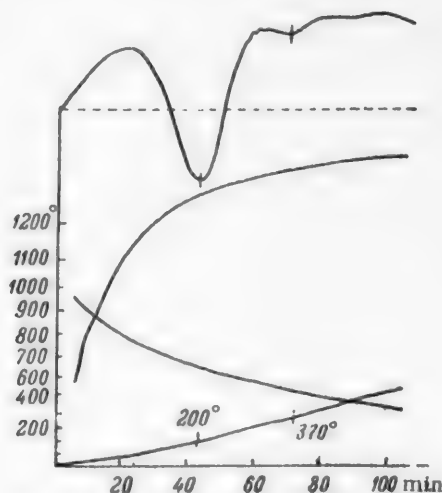


Fig. 4. Dissociation of solid solution NiO_2 - Ni_2O_3 , prepared at 100°.

air, with the resulting formation of a solid solution of it with the oxide, is detected to a noticeable degree even at 50°. The practically complete decomposition of pure nickel dioxide in air proceeds in the temperature interval of the order of 200-230°, while nickel oxide or its solid solutions with nickelous oxide are formed depending on the temperature of the dissociation. If the process is run after a prolonged hold of nickel dioxide at a relatively lower temperature, the dissociation temperature is raised somewhat (up to 260°). This is explained by the decrease of the dissociation pressure of nickel dioxide by lowering of its concentration in the solid solutions with nickel oxide under these conditions.

Nickel oxide (Ni_2O_3) is a considerably more stable compound in comparison with the dioxide; however, even this oxide has a rather high dissociation pressure. The beginning of the dissociation process of nickel oxide during its heating in air atmosphere is detected thermographically already at 320-330°. During the process of a prolonged isothermal hold to constant weight, the dissociation of nickel oxide was detected in air at even 300°. Thus, the temperature conditions of formation and stable existence of nickel oxide in pyrometal-

lurgical processes are limited by the quite narrow temperature boundaries. The process of dissociation of nickel oxide in air atmosphere is considerably developed even in the temperature range of 330-370°; however, its rate decreases materially on further elevation of the temperature. This confirms the previously established formation of solid solutions of nickel oxide and nickelous oxide and is explained by a material decrease of the magnitude of the change in free energy of the system during this process, owing to the decrease of the magnitude of dissociation pressure of nickel oxide with the decrease of its concentration in the solid solution which is undergoing the decomposition, the dissociation pressure being the determinant of the free energy change at a given temperature. The decline of the intensity of the dissociation process of nickel oxide with the decrease of its concentration in the solid solution is so considerable that, at temperatures above 500°, the progress of this process cannot be always detected by even quite sensitive methods of differential thermographic study. As it was shown experimentally, the dissociation process of nickel oxide proceeds under these conditions practically completely only at temperatures above 1100°. Nickelous oxide (NiO) is obtained here as the result of the dissociation.

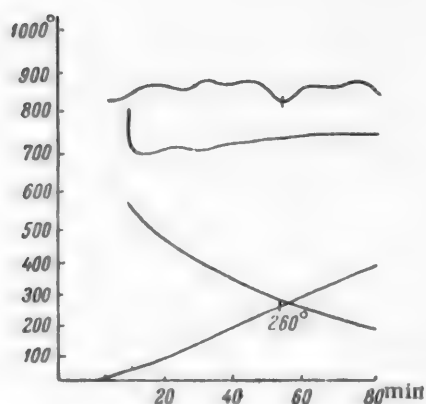


Fig. 5. Dissociation of solid solution of $\text{NiO}_2\text{-Ni}_2\text{O}_3$ prepared at 150°.

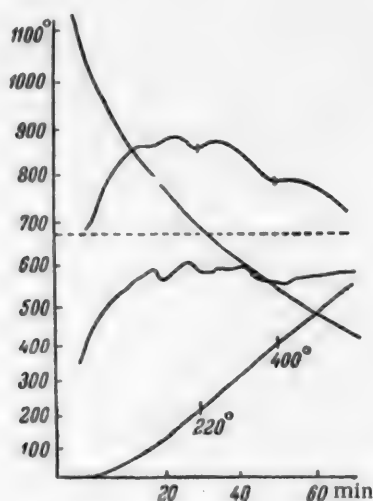


Fig. 6. Dissociation of solid solution of $\text{NiO}_2\text{-Ni}_2\text{O}_3$ prepared at 230° from nickel nitrate.

As to the nickel-nickelous oxide (Ni_3O_4) and the more than 25 other oxides described in the literature exceeds 25, the thermographic studies made by us failed to detect any signs of their existence despite the high sensitivity of the differential thermal method used. Thus, the thermographic study of the process of isobaric dissociation of the various oxygen compounds of nickel that was made by us shows that the only stable oxide of nickel, in the range of high temperatures, is nickelous oxide, in accord with the results of studies of this problem by other modern methods of physicochemical analysis [3].

The results of the thermographic study confirm the formation of a continuous series of solid solutions of nickel oxide and nickelous oxide and its dioxide, the limits of whose solubility need to be refined, in the system of nickel-oxygen, as established by us previously [4]. The concentration of nickel oxide in these solid solutions, and consequently their chemical composition, is determined by the temperature of the termination of the process of thermal dissociation of the dioxide, nickel oxide, or of their solid solutions obtained in the region of lower temperatures.

For an additional verification of these conclusions, we ran a roentgenographic study of the structure of the resulting oxides and of their solid solutions.*

*The roentgenographic studies were run in the laboratory of A. A. Bochvar, N. V. Ageev and E. S. Makarov.

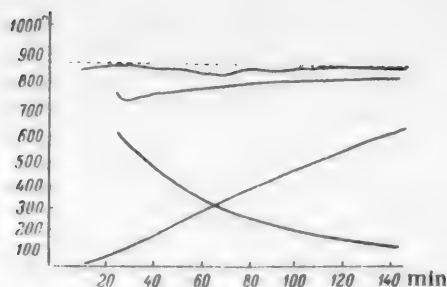


Fig. 7. Thermogram of nickel oxide, prepared from NiO_3 at 200° .

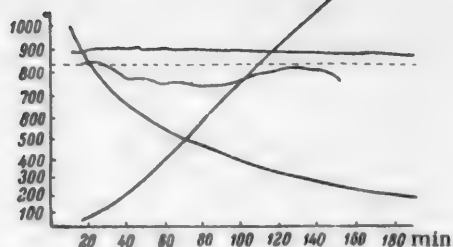


Fig. 8. Thermogram of nickel oxide, prepared from the nitrate at 250° .

The crystal lattice constants were determined by the Straumanis method. Specimens of pure nickel dioxide and oxide and nickelous oxide as well as their solid solutions, prepared by various methods, were subjected to the study for the establishment of the dependence of the structure of the crystal lattice on the chemical composition. The solid solutions subjected to this study were prepared by an isothermal hold to a constant weight in air of nickel dioxide and oxide at 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, and 1250° .

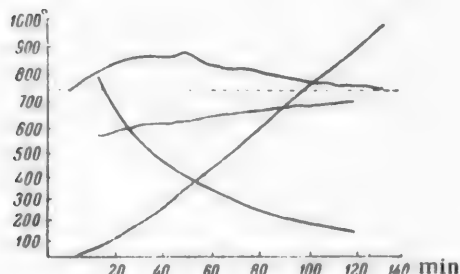


Fig. 9. Thermogram of solid solution of NiO in Ni_2O_3 prepared at 250° .

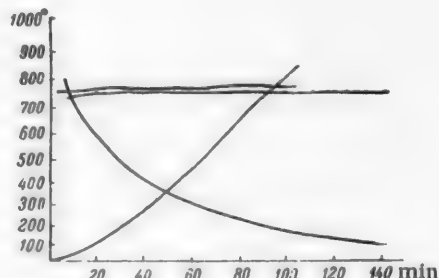


Fig. 10. Thermogram of solid solution of NiO in Ni_2O_3 prepared at 400° .

It was established as a result of these roentgenographic studies (Table 1) that nickel dioxide prepared by dehydration of its hydrate under high pressure has a cubic lattice with the constant equal on the average to 4.620 Å. The roentgenogram of nickel dioxide prepared by dehydration of the hydrate in the cold under vacuum indicates the extremely small dimensions of its crystals (of the order of 10^{-7} cm) which, however, still clearly show roentgenographically after heating to 50° . The nickel oxide has an edge centered cubic lattice with the parameter of 4.186 Å. Nickelous oxide has a crystal lattice of sodium chloride type with the constant equal to 4.172 Å.

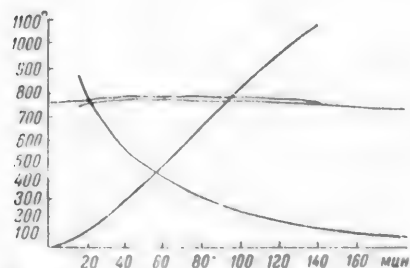


Fig. 11. Thermogram of solid solution of Ni_2O_3 in NiO prepared at 600° .

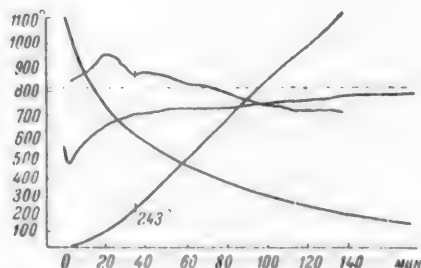


Fig. 12. Thermogram of nickelous oxide.

TABLE 1

Roentgenogram of Nickel Dioxide Prepared under High Pressure. λCu ; $\theta = 0.9927 \text{ } l_1$

No in order	Intensity	l_1	θ	$\sin \theta$	(hkl)	$a \text{ (}\AA\text{)}$
1	strongly differentiated	17.0	16°52'	0.2900	(111)	4.594
2	strong, very differentiated	19.4	19°15'	0.3297	(200)	4.667
3	weak, very differentiated	22.0	21°50'	0.3719	(120)	4.626
4	very weak, strongly differ.	26.3	26°06'	0.4399	—	—
5	medium sharp	30.2	29°59'	0.4997	(112) (300)	4.620
6	medium diffuse	31.8	31°34'	0.5236	(130)	4.647
7	very weak, strongly differ.	36.5	35°14'	0.6769	(222)	4.620
8	weak, differentiated	37.0	36°44'	0.5981	(230)	4.638
9	very weak, very differ.	51.7	51°19'	0.7806	(332)	4.623
10	very weak, very differ.	57.0	56°35'	0.8347	(500)	4.609

$a_{av} = 4.620 \text{ } \AA$

TABLE 2

Roentgenogram of Nickel Oxide. λCu ; $\theta = 0.98901 \text{ } l_1$

No in order	Intensity	l_1	θ	$\sin \theta$	(hkl)	$a \text{ (}\AA\text{)}$
1	strong	18.6	18°23'	0.3154	(111)	—
2	very strong	21.6	21°22'	0.3543	(200)	—
3	strong	31.4	31°03'	0.5158	(220)	—
4	strong	37.8	37°23'	0.6071	(311)	—
5	medium	39.7	39°15'	0.6327	(222)	—
6	medium	47.6	47°04'	0.7321	(400)	—
7	medium	53.7	53°06'	0.7997	(331)	4.194
8	strong	55.8	55°11'	0.8210	(420)	4.191
9	strong	65.0	64°17'	0.9009	(422)	4.184
10	strongly differentiated	73.8	72°59'	0.9562	(511) (333)	4.181

$a_{av} = 4.186 \text{ } \AA$

TABLE 3

Roentgenogram on Nickelous Oxide. λCu ; $\theta = 0.99392 \text{ } l_1$

No in order	Intensity	l_1	θ	$\sin \theta$	(hkl)	$a \text{ (}\AA\text{)}$
1	strong	19.0	18°53'	0.3236	(111)	—
2	very strong	22.0	21°52'	0.3724	(200)	—
3	very strong	31.7	31°30'	0.5225	(220)	—
4	strong	38.0	37°46'	0.6124	(311)	—
5	medium	40.0	39°45'	0.6394	(222)	—
6	medium	47.8	47°30'	0.7373	(400)	—
7	medium	53.8	53°28'	0.8035	(331)	4.173
8	strong	55.9	55°33'	0.8246	(420)	4.173
9	strong	65.0	64°36'	0.9033	(422)	4.173
10	strong	73.7	73°15'	0.9576	(511) (333)	4.171
11	medium	74.0	73°33'	0.9591	(511) (3,3)	4.174

$a_{av} = 4.172 \text{ } \AA$

The roentgenographic study of the structure of nickel oxide (Table 2) and nickelous oxide (Table 3) as well as that of the phases intermediate in composition (Table 4) confirm in principle the formation and the existence of a continuous series of solid solutions among these oxides in the system of nickel-oxygen.

TABLE 4

Results of Roentgenographic Study of Continuous Series of Solid Solutions of Nickel Oxides in the System Nickel-Oxygen

Temperature of preparation	a (Å)	Temperature of preparation	a (Å)
250°	4.186	800°	4.180
300	4.185	900	4.180
400	4.184	1000	4.180
500	4.184	1100	4.172
600	4.183	1250	4.172
700	4.181		

The appearance of the weakly displayed interference lines on the roentgenograms of the dissociation products of nickel dioxide at temperatures from 100° to 200°, these lines belonging to nickel oxide, as well as their character give grounds to suppose the existence of a limited solubility of nickel dioxide in the oxide in the solid state. The diffuse state and the washed-out appearance of the lines on the roentgenograms of these specimens, owing to the extremely small dimensions of the crystals (of the order of 10^{-6} - 10^{-7} cm), do not allow one to solve this problem with considerable certainty and this requires an additional study by special methods. The true physicochemical nature of the solid solutions between nickel oxide and nickelous oxide which have been shown in the system of nickel-oxygen also is insufficiently clarified and needs an additional study.

The experimental (Table 4) and the calculated data shown here for the roentgenographic studies made by us (Table 5) indicate that with rise of oxygen content in the solid solutions of nickel oxide and nickelous oxide, the parameter of the crystal lattice increases somewhat which confirms the experimental data on this

TABLE 5

Chemical Composition, Density, and Number of Atoms in the Elemental Cell of Nickel Oxides Studied by Us and Their Solid Solutions.

Temp. of preparation	Nickel content (weight %)	Oxygen content (weight %)	Mean atomic weight	Volume of elemental cell	Density	Number of atoms per cell
250°	70.91	60.1	33.058	73.3496	5.13	6.89
300	72.9	57.7	34.059	73.2970	5.30	6.91
400	75.4	54.5	35.448	73.2445	5.58	6.99
500	76.9	52.4	36.311	73.2970	5.74	7.02
600	77.9	54.0	36.927	73.1920	5.90	7.09
700	78.2	50.5	37.119	73.0870	6.02	7.18
800	78.4	50.3	37.243	73.0346	6.15	7.31
900	78.5	50.1	37.299	73.0346	6.28	7.45
1000	78.5	50.1	37.299	73.0670	6.41	7.61
1100	78.58	50.0	37.369	72.6161	6.46	7.61

matter obtained earlier by V. I. Arkharov and K. M. Graevskii [5]. The increase of the lattice constant with increased oxygen content in these solid solutions led the authors, without any other experimental basis, to suppose that oxygen, by dissolving in nickelous oxides, penetrates its lattice which leads to the increase of its param-

eter. However, this supposition was not based on any other proofs, as for example, a study of the number of atoms in the elemental cell of these oxides.

If a penetration of oxygen atoms into the nickelous oxide lattice, which is constructed according to the lattice type of rock salt, actually had taken place, the number of atoms per elemental cell as calculated from the data on density and elemental cell volume would have increased with increased oxygen content in the solid solutions studied. However, as it is shown by the calculations made by us (Table 5), the number of atoms per elemental cell does not increase and, conversely, actually decreases with the rise of oxygen content in the solid solutions studied. In agreement with the results of roentgenographic study made by Gitti and Futi [6] on the austenite phase in the system iron-oxygen, this could be explained by the fact that instead of penetration of oxygen atoms into the nickelous oxide lattice of sodium chloride type, there occurs a loss of nickel atoms from some tie-points of the lattice of nickelous oxide. Thus, if one regards the continuous series of solid solutions between nickel oxide and nickelous oxide as a series of solid solutions of oxygen in nickelous oxide, then one should consider that these solid solutions are constructed not according to the type of penetration of oxygen atoms into the nickelous oxide lattice, but according to the type of solid solutions formed by loss of nickel atoms from nickelous oxide lattice. However, this interpretation of the physicochemical nature of these solid solutions does not explain the increase of the parameter of their crystal lattice which had been established. The existing hypotheses are not cited here.

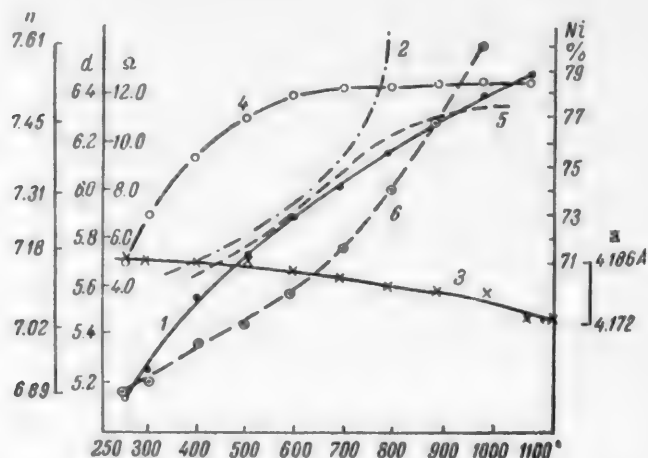


Fig. 13. Composition and physical properties of solid solutions of nickel oxides prepared at various temperatures. 1) Specific gravity; 2) specific resistivity; 3) parameter of crystal lattice; 4) nickel content; 5) density (according to Prasad); 6) number of atoms per elemental cell of the crystal lattice.

The study of the as yet insufficiently clarified physicochemical nature of the mutual solid solutions of nickel oxide and nickelous oxide is being continued by us. The existence of an inhomogeneity in the system nickel-oxygen between nickel oxide and nickelous oxide may be regarded as having been finally proven. The formation of solid solutions of nickel oxide and nickelous oxide, connected with the alteration of the crystal lattice parameter, partly explains the different results obtained from the determinations of the lattice constant for nickelous oxide cited by various authors [4].

No signs of the existence of nickelous-nickel oxide could be shown by thermographic, roentgenographic, magnetometric studies and other means of physicochemical analysis [7] (Fig. 13). This confirms the supposition made by us previously [1] that the nickelous-nickel oxide described as a stable oxide is actually a solid solution of nickel oxide and nickelous oxide which in its composition fits accurately the appropriate formula for the nickelous-nickel oxide. This is fully confirmed by other methods of study [8].

In conclusion, the authors express their sincere gratitude to I. I. Chernyaev, A. A. Bochvar, N. V. Ageev, L. G. Berg, and E. S. Makarov for the cooperation and aid during the course of this study.

SUMMARY

1. The results of thermographic and roentgenographic studies made by us confirm the existence of only nickel dioxide, nickel oxide, and nickelous oxide, as well as solid solutions of these oxides discovered by these and other methods of physicochemical analysis.

2. Nickel dioxide prepared by dehydration of its hydrate under high pressure has a cubic lattice with the parameter equal to 4.620 Å. Nickel oxide has the edge-centered cubic lattice with parameter equal to 4.186 Å. Nickelous oxide has an edge-centered cubic lattice with parameter equal to 4.172 Å.

3. No signs of the existence of nickelous-nickel oxide and other oxides in the system nickel-oxygen are detected by thermographic and roentgenographic studies or by any other method of physicochemical analysis.

LITERATURE CITED

- [1] D. P. Bogatskii, *J. Gen. Chem.* 7, 1397 (1937).
- [2] D. P. Bogatskii, *Bull. Acad. Sci. USSR, Ser. Chem.* 1956, 1159. *
- [3] D. P. Bogatskii, *Coll. Sci. Works of Moscow Inst. of Nonferrous Metals*, 1938, No. 6, p. 58.
- [4] D. P. Bogatskii, *Metallurgist (USSR)* 1937, 58; *Dissertation, Inst. Gen. Inorg. Chem. Acad. Sci. USSR* (1945). **
- [5] V. I. Arkharov and K. M. Graevskii, *J. Tech. Phys.* 14, 132 (1944).
- [6] D. P. Bogatskii, *Metallurgist (USSR)* 1956, p. 64.
- [7] D. P. Bogatskii, *Bull. Acad. Sci. USSR, Ser. Chem.* 1947, 105.
- [8] D. P. Bogatskii, *J. Gen. Chem.* 21, 3 (1951). *

Received December 25, 1957

* Original Russian pagination. See C.B. Translation.

** In Russian.

REGULARITIES IN PROPERTIES OF THALLIUM

I. M. Korenman

Gor'kii State University

The chemical properties of thallium have long attracted attention by the fact that in some respects they resembled the heavy metals (lead, silver, gold) and in others were analogous to the properties of the alkali metals [1]. This peculiarity was pointed out by D. I. Mendeleev [2], V. I. Vernadskii [3] and other authors. The combination of so greatly differently properties in the same element gave the foundation for calling thallium a mysterious element [3] or even a paradoxical metal [4-6]. Should this diversity of properties of thallium be regarded as a paradox, as an exception to the general regularity connected with the position of an element in the D. I. Mendeleev system of the elements? The present paper is devoted to this problem.

We were interested in: 1) properties directly connected with the position of thallium in Group III of the elements, 2) analogy with the alkali metals, 3) analogy with the heavy metals of Group I, and 4) the analogy with the nearest neighbors in the Sixth Period.

The properties of thallium, as an analog of gallium and indium, are well known and we shall not pause here. We shall note only that thallium, like all elements of Group III, can yield compounds in which maximum valence is displayed, this being equal to three. Along with the similarity of thallium and the elements of Group III which precede it, one should also note the differences. The most important difference is the ability to thallium to yield stable compounds in which it is monovalent. This peculiarity of thallium was explained by L. H. Arens [7] as an increase of screening of the nuclear positive charge by introduction of the additional electrons in the outer orbits; the same leads to increased atomic radii. The valence electrons in s and p orbits become freer and the element of higher atomic weight acquires a variable valence. In the thallium atom, the heaviest representative of elements of thallium subgroup, the attraction of the outer electrons by the nucleus is most weak and therefore the $6p$ electron is held least strongly. The variable valence of thallium and its ability to enter oxidation-reduction reactions distinguish thallium from the elements of Group III which precede it. Many compounds of monovalent thallium are similar to the corresponding compounds of the alkali metals. This may be explained by the same valence of the cations of the alkali metals and thallium and the very close dimensions of their ionic radii:

Cation	K ⁺	Rb ⁺	Tl ⁺	Cs ⁺
Radius (Å)	1.33	1.49	1.49	1.65

Therefore, thallium compounds are isomorphous with the corresponding compounds of the alkali metals and often form mixed crystals with them. The similarity of thallium with the alkali metals may be illustrated for example by the good solubility of $TlOH$ in water. Salts of potassium, rubidium, cesium, and thallium often yield precipitates with the same reagents.

L. H. Arens [7] indicates that thallium differs from the alkali metals by the low solubility of its sulfide and chloride. Of course, thallium as a heavy element of Group III should differ even in the monovalent state from the lighter elements of Group I elements.

It should be also recalled that monovalent thallium, in contrast to the alkali metals, also forms other difficultly soluble compounds. Here we pass into the area of other properties of Tl^+ , which bring it closer to the monovalent cations of heavy metals of Group I (Cu^+ , Ag^+ , Au^+) and the properties of its closest neighbors in the

Sixth Period of the D. I. Mendeleev System (Hg^{2+} , Hg^{+} , Pb^{2+} and partly Bi^{3+}). Thallium, like the indicated ions, forms sulfides, iodides, chromates, molybdates, etc., which are difficultly soluble in water. The halogen salts of Tl^{+} are light-sensitive which brings them close to the corresponding salts of Ag^{+} and Au^{+} .

Thus, in one series of properties the monovalent thallium resembles the elements of the main subgroup of Group I, and in another series of properties — the elements of the side subgroup of the same Group (as well as Hg , Pb , and Bi). We shall add that while Tl^{+} resembles in many respects the behavior of Au^{+} , Tl^{3+} on the other hand has a series of properties which are close to Au^{3+} (and Bi^{3+}), as for example: the ability to be extracted with organic solvents from solutions in halogen acids, formation of compounds of type $[\text{RX}_4]^{+}$ some of which are characterized by low solubility in water.

It is timely to pose the question: is such a multiplicity of properties a peculiar, actually exclusive symptom of thallium? May not a similar multiplicity be noted in other elements? In order to answer this question we turn our attention to the almost identical structure of the electron shells of thallium, lead, bismuth, polonium, and astatine. The difference is noted in 6p orbitals.

Atoms of these elements, in giving up electrons of 6p orbital, are transformed into cations with the same electron shell structure, whereupon $18 + 2$ electrons appear in the outer shells. This permits us to suppose a certain similarity of properties among them and, specifically, the multifaceted chemical character (see table). In reality, while compounds of Tl^{+} are similar to the corresponding compounds of elements of Group I, lead resembles the alkaline earth metals in a number of properties. Here, we again see the same valence and the very close cation radii:

Cation	Ca^{2+}	Sr^{2+}	Pb^{2+}	Ba^{2+}
Radius (Å)	1.06	1.27	1.32	1.43

Among the properties which bring together lead and the alkaline earth metals, we shall note the low solubility of sulfates, chromates, fluorides, rhodizonates, and compounds of composition $\text{K}_2\text{R}[\text{Cu}(\text{NO}_2)_6]$, as well as the ability of lead salts to yield mixed crystals with salts of the alkaline earth metals, especially barium and strontium. On the other hand, one notes the similar properties of lead and the elements of the zinc subgroup, especially mercury (formation of complex halides, solubility of sulfides in acid solutions of potassium iodide, and others).

Bismuth has some points of resemblance with the alkaline earth elements. These are displayed in formation of difficultly soluble double sulfates of composition $\text{R}_2(\text{SO}_4)_3 \cdot 3\text{K}_2\text{SO}_4$, compounds of composition $\text{Cs}_2\text{Na}[\text{R}(\text{NO}_2)_6]$, isomorphism of double nitrate $2\text{Bi}(\text{NO}_3)_3 \cdot 3\text{Mg}(\text{NO}_3)_2$ with the corresponding salts of some alkaline earth elements. The similarity of some properties of Bi^{3+} and Tl^{3+} was already noted by us previously. Thus, thallium, lead and bismuth, belonging to III–V Groups are similar in some properties with elements of I–III Groups respectively. It is interesting to note here that it is specifically owing to these circumstances that D. I. Mendeleev placed, in an early variant of the periodic system which appeared in the beginning of 1869 [8, 9], thallium in the same group

	I	II	III	IV	V	VI	VII
II	Cs	Ba	Tl	Pb	Bi	Po	At
III	Ag	Cd	In	Sn	Sb	Te	I
IV							
V							
VI							
VII							

with potassium, rubidium, and cesium, while lead was put in the same group with the alkaline earth metals, while bismuth was held in some properties to be an analog of aluminum (same valence and, especially, the amphoteric character of R_2O_3). However, by the middle of 1869, D. I. Mendeleev moved these three elements two places to the right in accordance with the properties of the higher oxides. The closeness of number of properties of thallium, lead and bismuth may be also illustrated by the fact that in the first edition of "Foundations of Chemistry", D. I. Mendeleev regarded these three elements in the same chapter [10]. One may suppose that the analogy of the properties of Tl^{+} , Pb^{2+} and Bi^{3+} could be explained by the above-noted similar structure of the electron shells of these cations. It is true that the multiplicity of properties of leads, and especially bismuth, is shown less sharply than it is in thallium. Polonium and astatine, in their 4- and 5-valent states respectively, have the same structure of the electron shells as the three elements which precede them in the Sixth Period. Therefore, it is possible to expect a similarity of the properties of polonium with zirconium and hafnium as well as lead. The similarity of polonium

in some respects with lead has been actually noted already [11]. Astatine has been studied but little so far, but in analogy with the above one may count on its certain resemblance with tantalum and bismuth. In any case, the ability to be precipitated with hydrogen sulfide from a strongly acid solution [12] distinguishes astatine from other halogens and brings it closer to bismuth and other heavy metals. Speaking of astatine, S. E. Bresler [11] notes that "the properties of the metal and the halogen are curiously combined in this element". Consequently, one may see a definite regularity, and not a paradox, in the multiplicity of the properties of thallium, as well as those of lead, bismuth, polonium and astatine.

Everything said above allows us to repeat the words of D. I. Mendeleev [2]: "The entire totality of other data of the chemical and the physical properties of thallium, its two stages of oxidation and the salts corresponding to them are expressed by the place which is occupied by this metal in accord to its atomic weight $Tl = 204$ between mercury $Hg = 200$ and lead $Pb = 207$ ".

SUMMARY

1. It was shown that the multiple properties of thallium are caused by its position in the system of the elements devised by D. I. Mendeleev.

2. It was shown that a similar but not so clearly displayed multiplicity of properties is observed for other elements as well in the Sixth Period, whose cations have $18 + 2$ electrons in the outer shells.

LITERATURE CITED

- [1] A. Lamy, Lieb. Ann. 67, 385, 418 (1862) [cited from N. N. Mel'nikov, Advances in Chem. 4, 255 (1935)]
- [2] D. I. Mendeleev, "Foundations of Chemistry", State Chem. Tech. Press (1934).*
- [3] V. I. Vernadskii, Selected Works, Publ. Acad. Sci. USSR (1954).*
- [4] Handbook of Chemistry and Physics, ed. S. D. Hodman (1955).
- [5] N. V. Belov, Nature (USSR) 21, 162 (1932).
- [6] L. I. Iskol'dskii, Thallium, Chemistry and Technology, Nonferrous Metal Press (1933).*
- [7] Rare Elements in Extruded Minerals and Mountain Structures, translated under edit. V. V. Shcherbina, Foreign Press (1952).*
- [8] D. I. Mendeleev, New Materials on History of Discovery of the Periodic Law, publ. Acad. Sci. USSR (1950).*
- [9] D. I. Mendeleev, Sci. Archive, vol. 1, publ. Acad. Sci. USSR (1953).*
- [10] D. I. Mendeleev, Works, vol. 14, publ. Acad. Sci. USSR, 873 (1949).*
- [11] S. E. Bresler, Radioactive Elements, Publ. Tech. Theoret. Lit. (1952).*
- [12] Chemistry of Isotopes, translated under ed. Ya. K. Syrkin, Coll: vol. No. 1, Foreign Press, 59 (1948).*

Received January 16, 1958

* In Russian.

** Russian translation.

EFFECT OF SOME ELECTROLYTES ON SOLUBILITY OF BENZOIC ACID IN WATER

V. F. Sergeeva and M. I. Usanovich

Kazakh State University

The solubility of benzoic acid in aqueous salt solutions has been studied by a number of workers [1-5]. In the present paper we present some data on the solubility of benzoic acid in aqueous solutions of sodium chloride, lithium chloride, potassium iodide, tetramethylammonium iodide, tetraethylammonium iodide, and ethylpyridinium iodide.*

0.01 N sodium benzoate was added to the solution for suppression of dissociation of benzoic acid. The solubility was determined by the thermographic method. The results of the measurements are given in Table 1 (N - mole fraction of benzoic acid) and in Fig. 1 in the form of the dependence of $\lg N$ on $1/T$.

It is evident from the figure that LiCl, NaCl, and KI decrease the solubility of benzoic acid in water, while $(CH_3)_4NI$, $(C_2H_5)_4NI$ and $C_5H_5NC_2H_5I$ increase it.

TABLE 1
Solubility of Benzoic Acid

Temperature	N	Temperature	N	Temperature	N	Temperature	N
Water		N solution of NaCl		N solution of LiCl		N solution of $(C_2H_5)_4NI$	
45.3°	0.00099	67.0°	0.00154	73.0	0.00200	39.2	0.00281
53.8	0.00146	71.5	0.00187	78.0	0.00272	42.8	0.00323
62.5	0.00206	83.0	0.00307	84.8	0.00303	49.1	0.00443
69.4	0.00280	89.0	0.00416	90.0	0.00418	55.5	0.00583
79.0	0.00415	—	—	—	—	63.4	0.00800
82.3	0.00477	—	—	—	—	68.0	0.0110
88.6	0.00799	—	—	—	—		
N solution of KI		N solution of $C_5H_5NC_2H_5I$		0.25N solution of $(CH_3)_4NI^{**}$			
67.5	0.00196	33.0	0.00217	59.2	0.00208	72.1	0.0138
73.5	0.00239	50.7	0.00395	72.0	0.00339	74.7	0.0171
77.7	0.00300	55.7	0.00457	81.6	0.00468	77.8	0.0208
81.6	0.00363	70.0	0.00822			80.2	0.0257
		73.2	0.00999				
		75.0	0.01029				
		79.1	0.01157				

* $(CH_3)_4NI$ is only slightly soluble in water.

** The experimental part was carried out by student T. Semenova.

The values of constant K in Sechenov's equation [6] $\lg \frac{S_0}{S} = K_C$, calculated on the basis of the experimental data, are given in Table 2. They are related to temperature 71.6°.

The values of the salting-out constants indicate the specificity of action of the salts on solubility of benzoic acid.

TABLE 2

Electrolyte	K
LiCl	0.205
NaCl	0.206
KI	0.115
$(CH_3)_4NI$	-0.200
$(C_2H_5)_4NI$	-0.620
$C_5H_5NC_2H_5I$	-0.480

These data do not fit the Debye and McAulay equation [7] which does not consider the possibility of salting-out. The theoretical considerations by a number of authors [8-13], while suggesting the possibility of salting-out action of the large ions, can hardly explain the considerable individual differences found by us in the action of salts on the solubility of benzoic acid in water.

Therefore, we decided to study the appropriate binary systems (without water) for the clarification of the specific relationships of our electrolytes with benzoic acid. It turned out that sodium chloride does not cause a lowering of melting point of benzoic acid. Tetramethylammonium iodide causes a depression, but the extended nature of the liquidus of benzoic acid is very small. The data on the solubility of benzoic acid in ethylpyridinium and tetraethylammonium iodides are given in Table 3, from which it is evident that tetraethylammonium ion is the best solvent for benzoic acid.

Comparing the data on the effect of salts on the solubility of benzoic acid in water with the data on fusion of the appropriate binary systems, we see that sodium chloride which does not cause a depression of the melting point of benzoic acid, i.e., which does not dissolve the latter, produces a salting-out action. The salts

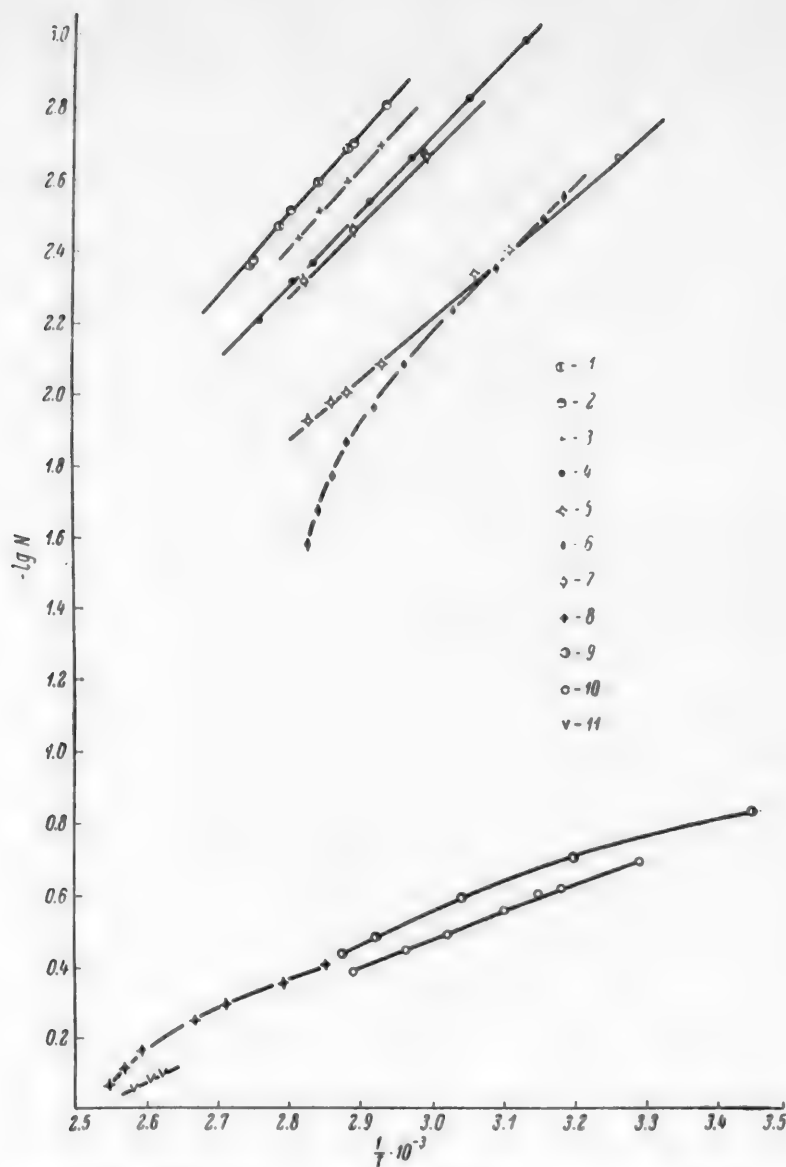
TABLE 3

$C_6H_5COOH-C_6H_5NC_2H_5I$				$C_6H_5COOH-(C_2H_5)_4NI$	
Temperature	N	Temperature	N	Temperature	N
121°	1.00	101°	0.570	121°	1.00
119	0.858	93	0.510	113	0.878
116	0.764	86	0.458	110	0.818
113	0.690	77	0.390	108	0.789

TABLE 4

$C_6H_5COOH-C_6H_5OH$				N solution of $C_6H_5NC_2H_5I$ in alcohol	
Temperature	N	Temperature	N	Temperature	N
31.0°	0.204	58.0°	0.327	17.3°	0.147
41.6	0.245	64.3	0.354	39.6	0.198
44.0	0.251	72.4	0.415	55.8	0.259
47.7	0.278			69.3	0.327
				76.5	0.359

which are better solvents for benzoic acid than is water, on the other hand raise the solubility of benzoic acid in water. Here, tetraethylammonium iodide, which is the best solvent for benzoic acid among all the salts studied by us, produces the greatest effect on salting-in.



Solubility of benzoic acid. 1) In N NaCl solution; 2) in N LiCl solution; 3) in N KI solution; 4) in water; 5) in N $C_5H_5NC_2H_5I$ solution; 6) in N $(C_2H_5)_4NI$ solution; 7) in 0.25 N $(CH_3)_4NI$ solution; 8) in $C_5H_5NC_2H_5I$; 9) in N $C_5H_5NC_2H_5I$ solution in alcohol; 10) in C_2H_5OH ; 11) in $(C_2H_5)_4NI$.

Considering that the regularity thus established has a general significance, we studied the solubility of benzoic acid in ethyl alcohol and in N solution of ethylpyridinium iodide in ethyl alcohol (Table 4).

It is evident from the data in Table 4 that with the addition of ethylpyridinium iodide to the alcohol there occurs a salting-out of benzoic acid rather than a salting-in as in aqueous solution. A comparison of the data on solubility of benzoic acid in alcohol and ethylpyridinium iodide indicates that alcohol is the better solvent of these two substances.

Thus, the salting-out observed in this case fits the proposed general regularity.

SUMMARY

1. The solubility of benzoic acid in water and in aqueous solution of NaCl, LiCl, KI, $(\text{CH}_3)_4\text{NI}$, $(\text{C}_2\text{H}_5)_4\text{NI}$, and $\text{C}_5\text{H}_5\text{NC}_2\text{H}_5\text{I}$ was studied. Sodium and lithium chlorides and potassium iodide reduce the solubility of benzoic acid in water. Tetramethylammonium iodide, tetraethylammonium iodide and ethylpyridinium iodide increase the solubility of benzoic acid in water.

2. The solubility of benzoic acid in tetraethylammonium iodide and ethylpyridinium iodide was studied and it was shown that these electrolytes are good solvents for benzoic acid.

3. A supposition was expressed which explains the salting-in effect. The increase of solubility of nonelectrolytes after the addition of electrolytes occurs in such cases in which the added electrolyte is a better solvent for the given nonelectrolyte than is water.

4. The solubility of benzoic acid in ethyl alcohol and in an alcoholic solution of ethylpyridinium iodide was studied. Ethylpyridinium iodide lowers the solubility of benzoic acid in alcohol. The salting-out effect was explained similarly to the salting-in effect.

LITERATURE CITED

- [1] P. A. Paul, J. Am. Chem. Soc. 75, 2513 (1953).
- [2] J. Morrison, Trans. Far. Soc. 40, 43 (1944).
- [3] I. N. Sarmousakis and M. J. Low, J. Phys. Chem. 60, 1139 (1956).
- [4] G. M. Goeller and A. Osol, J. Am. Chem. Soc. 59, 2132 (1937).
- [5] A. Osol and M. Kilpatrick, J. Am. Chem. Soc. 55, 4430 (1933).
- [6] I. M. Sechenov, Collected Works, vol. 1 (1907).*
- [7] P. Debye and J. Mc Aulay, Phys. Z. 26, 22 (1925).
- [8] F. A. Long and W. F. McDevit, Chem. Rev. 51, 119 (1952).
- [9] W. F. McDevit and F. A. Long, J. Am. Chem. Soc. 74, 1775 (1952).
- [10] R. Z. Bergen and F. A. Long, J. Phys. Chem. 60, 1131 (1956).
- [11] J. O. M. Bockris, J. Bowler-Reed, and J. A. Kitchener, Trans. Far. Soc. 47, 184 (1951).
- [12] J. H. Saylor, A. I. Whitten, I. Claiborne, and P. M. Gross, J. Am. Chem. Soc. 74, 1778 (1952).
- [13] A. P. Altshuller and H. E. Everson, J. Am. Chem. Soc. 75, 4823 (1953).

Received February 10, 1958

* In Russian.

LETTERS TO THE EDITOR

SPECTRAL STUDY OF AROMATIC DIAZO COMPOUNDS*

B. A. Poral-Koshits and B. V. Passet

Lensovet Technological Institute, Leningrad

The study of the absorption spectra made for aromatic diazo compounds in acid medium after the establishment of equilibrium showed that a strong absorption in the interval of 260-280 m μ is characteristic for the diazo cations. The absorption curves of diazo compounds in an alkaline medium show absorption maxima at 275-330 m μ . In the region of medium values of pH (from 7 to 9) the absorption curves occupy an intermediate position between the first two. The absorption curves of any diazo compound intersect in one point at all values of pH. The existence of isosbestic points indicates that regardless of the pH values almost no other forms of the diazo compounds, except for the diazo cation and the diazo anion, exist in aqueous solutions after the establishment of equilibrium. This idea had been previously expressed by Wittwer and Zollinger [1] but did not have sufficient experimental proof. Below, we present the table of isosbestic points for several diazo compounds.

Diazo compound	Absorption maxima (in m μ)		Position of isosbestic points (in m μ)
	of cation	on diazo anion	
o-Methoxydiazobenzene	266, 355	223, 273	250, 274, 327
Diazobenzene	263, 300	273	245, 268
p-Sulfodiazobenzene	269, 310	281	245, 278
p-Nitrodiazobenzene	260, 312	330	238, 280
2,6-Dichlorodiazobenzene	277, 347	< 220	248

Simultaneously and independently of us, the existence of isosbestic points was shown by Lewis and Suhr [2] for p-nitrodiazobenzene. However, they were unable to study the established equilibrium and therefore made a number of wrong conclusions and noted themselves the small degree of accuracy of the physicochemical calculations obtained on the basis of the study of the spectral characteristics. The authors of the present work had provided the method of a rapid determination of concentrations of the diazo compound. Having ascertained the obedience of the dilute aqueous solutions of the diazo compound under all values of pH to the Lambert-Beer law and making use of Firort's method [3] with separate determination of the amounts of diazo cation and diazo anion, we were able to refine the values of the hydrolysis constant of the diazo cation made previously by means of other analytical methods [4], this value turning out to be, according to these sufficiently accurate data, equal to $k = 6.3 \cdot 10^{-16}$; the acidity constant of p-nitrophenylnitrosamine $k = 2.5 \cdot 10^{-6}$, the first acidity constant of p-nitrophenyl diazo cation $k_1 = 2.51 \cdot 10^{-10}$, and the first and the second basicity constants of diazo anion $k_{b1} = 1.6 \cdot 10^{-9}$ and $k_{b2} = 1.58 \cdot 10^{-5}$.

* Presented in April 17, 1957, at a session of Leningrad Section of All-Union Mendeleev Chemical Society and in May, 1957, at a session of Lodz Section of Polish Chemical Society.

** Transliteration of Russian - Publisher's note.

The study of the changes in the concentration of the diazo cation in the reaction with base, showed that this reaction does not obey the equation for a first order reaction; the reverse reaction of the diazo anion with acid proceeds in the initial moments as a first order reaction. This agrees with the data obtained by Lewis and Suhr.

LITERATURE CITED

- [1] C. Wittwer and H. Zollinger, *Helv. Chim. Acta*, 37, 1954 (1954).
- [2] E. Lewis and H. Suhr, *J. Am. Chem. Soc.* 80, 1367 (1958).
- [3] A. Gilliam, and E. Stern, *Electronic Absorption Spectra of Organic Compounds*, Foreign Press, 259 (1957).*
- [4] B. V. Passet and B. A. Porai-Koshits, *Works of Lensovet Technol. Inst. Leningrad*, No. XLVI, 134 (1958).**

Received January 15, 1958

* Russian translation.

** In Russian.

CONCERNING A RATIONAL METHOD OF EXPRESSING COMPOSITION IN THE STUDY OF DENSITIES OF SOLUTIONS

V. A. Mikhailov and A. A. Kamarzin

Institute of Inorganic Chemistry of the Siberian Division of Academy of
Sciences, USSR

It is known that if the formation of a system (for example an ideal solution or a mechanical mixture) is not accompanied by a change of volume, the density is an additive function of composition only with the expression of the latter in the form of volume fractions. With any other method of expression of composition, even for ideal solutions, the dependence of density on composition is not linear in a general case. The apparent deviations from additivity caused in this case by the inequality of molar volumes of the components (with expression of the composition in mole fractions) or by inequality of their densities (with the use of weight fractions) cannot provide any information about chemical interaction in the system and even about the values and the sign of alteration of volume after mixing. The additivity of density with the composition being expressed in volume fractions is proved for the ideal systems by a most elementary way (see for example [1]) and is actually self-evident.

Nevertheless, many authors [2-14] studying densities of binary solutions express the composition in mole fractions and, being guided by the shape of the resulting density-composition curves, attempted to draw conclusions about the intensity of chemical interaction in the system and about the volume change during its formation. This method of expressing composition in a study of density is completely unfounded and may lead to erroneous conclusions especially with large difference in molar volumes of the components. An example may be provided by the conclusion made by I. M. Bokhovkina [7] about the enhanced chemical interaction of acetone with chloro derivatives of acetic acid with the increased substitution of hydrogen by chlorine in the radical of acetic acid. This conclusion was based on the increased convexity of the density-composition curves in passing from acetic to trichloroacetic acid. In reality, however, the data on density do not support this conclusion since after expressing the composition in volume fractions, the differences between these curves are removed.

Similarly wrong is the calculation made by A. Ya. Deich [15] for density of a mixture of solutions with the "usual additivity formula" expressing composition in weight fractions with a subsequent comparison of this calculated density with the experimental value. A subsequent application of this method leads, for example, to the absurd conclusion on the existence of an intense chemical interaction on mixing water with mercury.

Thus, in studying densities of solutions the composition must be expressed in volume fractions. Only in this case will the shape of the density isotherm permit one to draw the correct conclusions about the change of volume during the formation of the system. Principally equivalent but a simpler method is the construction of the dependence of specific volume on composition, expressing the latter in weight fractions [16, 17]. Conclusions drawn by authors who used other methods to express the composition need a critical review.

LITERATURE CITED

- [1] V. Ya. Anosov and S. A. Pogodin, *Fundamental Principles of Physicochemical Analysis*, Acad. Sci. USSR 92, 152, 304 (1947).

- [2] I. M. Bokhovkin and Yu. I. Bokhovkina, J. Gen. Chem. 26, 1315 (1956).*
- [3] Yu. I. Bokhovkina and I. M. Bokhovkin, J. Gen. Chem. 26, 1318 (1956).*
- [4] Yu. I. Bokhovkina and I. M. Bokhovkin, J. Gen. Chem. 26, 1872 (1956).*
- [5] Yu. I. Bokhovkina, J. Gen. Chem. 26, 2399 (1956).*
- [6] I. M. Bokhovkin and E. G. Veselova, J. Gen. Chem. 28, 819 (1958).*
- [7] I. M. Bokhovkin, J. Gen. Chem. 28, 862 (1958).*
- [8] V. V. Udovenko and R. I. Khomenko, J. Gen. Chem. 26, 3270 (1956).*
- [9] N. Z. Rudenko and D. E. Dionis'ev, J. Gen. Chem. 23, 721 (1953).*
- [10] Z. K. Dzhelomanova, N. Z. Rudenko, and D. E. Dionis'ev, J. Gen. Chem. 26, 1322 (1956).*
- [11] Z. K. Dzhelomanova, N. Z. Rudenko and D. E. Dionis'ev, J. Gen. Chem. 26, 1866 (1956).*
- [12] N. K. Tsvetkova and D. E. Dionis'ev, J. Gen. Chem. 28, 868 (1958).*
- [13] Yu. A. Lysenko, J. Gen. Chem. 26, 2963 (1956).*
- [14] Yu. A. Lysenko, J. Gen. Chem. 26, 3273 (1956).*
- [15] A. Ya. Deich, J. Inorg. Chem. USSR 2, 903 (1957).
- [16] M. Usanovich and E. Pichugina, J. Gen. Chem. 26, 2130 (1956).*
- [17] T. Sumarokova and N. Khakhlova, J. Gen. Chem. 26, 2690 (1956).*

Received July 19, 1958

*Original Russian pagination. See C.B. Translation.

CONCERNING THE ERRORS OF THE "METHOD OF THE FOURTH COMPONENT"*

V. F. Boiko

Kuban Agricultural Institute

It was pointed out previously [2] that G. B. Fridman allowed some errors to enter both into the foundation of the "method of the fourth component" [3] and into the determination of composition of iron oxychloride by this method [4]. However, Fridman [1] attempts to prove the opposite; in his opinion, the errors are contained in our studies and not in his. Let us turn to the facts.

1. According to our data the positive adsorption of an indifferent component introduced into a finely dispersed system causes the appearance of negative adsorption of other components contained in the liquid phase of the system, as a result of displacement of the latter from the adsorbed layer of the solid phase. Since the adsorption of the displaced components is not eliminated and actually persists (only its sign is changed), the results of the determination of composition of the finely dispersed solid phase would be distorted to such a degree even before the introduction of the indifferent component into the system, if this adsorption is neglected.

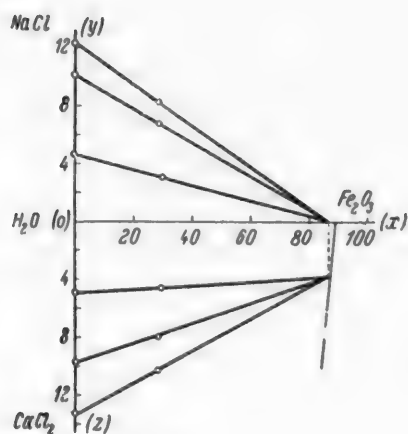


Fig. 1.

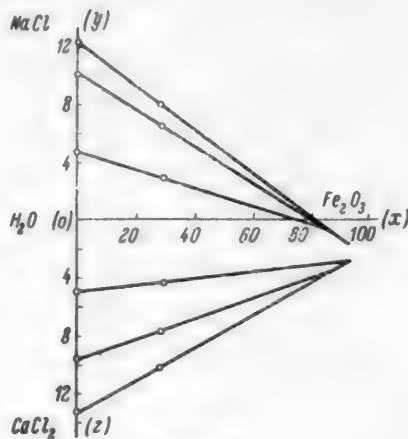


Fig. 2.

Fridman [1] discards the possibility of origination, under these conditions, of any negative adsorption. He bases his viewpoint on the results obtained in the study of the system $\text{Fe}_2\text{O}_3\text{-H}_2\text{O-NaCl-CaCl}_2$ [3] which he calls "experimental verification of the method of fourth component". In this "study" it was shown that introduction of the fourth component -CaCl_2 - into the ternary system $\text{Fe}_2\text{O}_3\text{-H}_2\text{O-NaCl}$ does not bring about

* A reply to the comments by G. B. Fridman [1] about our paper "A Study in the Field of Basic Iron Chlorides".

a negative adsorption of NaCl present in the liquid phase of the system. This is a gross error, however. In examining the cited experimental data from this study [3] it appears that the greater part of the analyses (six samples out of eight) are completely unsuitable for characterization of composition of the solid phase being studied. In addition, the diagram constructed, as asserted by the authors [3], from the analytical data, actually does not agree with these data. In order to be convinced of this, we cite the diagram given by Fridman (Fig. 1) and one constructed by us (Fig. 2) from the same analytical data [3]. A comparison of these diagrams shows that Fridman's viewpoint is based on erroneous conclusions taken contrary to facts. We repeated Fridman's experiment and found that the introduction of the fourth component - CaCl_2 - into the system in amounts sufficient to reach the limiting adsorption produced a negative adsorption of NaCl [5]. The magnitude of adsorption of CaCl_2 in this experiment reached 3.90% and the adsorption of NaCl was equal to 2.01%. Naturally, in determining the composition of iron oxychloride by the "method of the fourth component" without an allowance for the negative adsorption of FeCl_3 , Fridman obtained the wrong results as should have been expected [4].

2. The deviation of his data on the composition of iron oxychloride [4] from ours [2] is attemptedly explained by Fridman by the tendency of the oxychloride to be hydrolyzed, by asserting that we had failed to take the appropriate measures to prevent this hydrolysis. This assertion does not correspond to reality. In order to prevent hydrolysis we washed the resulting specimen of iron oxychloride with a solution containing the same ion (10% CaCl_2) in which the oxychloride is stable. But even if one expresses some doubt that the measures taken by us to suppress hydrolysis were quite sufficient, and this is not the main item, one can hardly argue that keeping of the sample in a CaCl_2 solution for six months is a sufficiently long period for the establishment of a hydrolytic equilibrium in the system, without any doubt. Nevertheless, after a further hold of the specimen in the same solution for 12 months longer an alteration of its composition occurred. Such changes in the composition of finely dispersed phases after a considerable interval of time have been observed by us among other objects of study [6]. We consider that this phenomenon is a result of an aging process of the finely dispersed phases.

3. The name of the method used by us as the method of an indifferent component (and not fourth) was caused first of all by the need to differentiate it from the "method of the fourth component". Besides a similarity, these methods have some differences consisting first of all in that the "method of the fourth component" in the form in which it is suggested by Fridman [3] is based on wrong premises, leads to errors, and is thus unsuitable for practical use, while the method proposed by us [5] may be used for the study of colloiddally dispersed systems.

We believe that the method of the fourth as well as the method of the fifth, sixth, and seventh components used by us, are special cases of a method of study of finely dispersed solid phases in multicomponent systems based on introduction of an indifferent component into the system, i. e., a method of an indifferent component.

LITERATURE CITED

- [1] G. B. Fridman, J. Gen. Chem. 27, 2019 (1957).*
- [2] V. F. Boiko, J. Gen. Chem. 25, 1950 (1955).*
- [3] P. T. Danil'chenko and G. B. Fridman, Colloid. J. 10, 1 (1948).
- [4] G. B. Fridman, Bull. Crimean Pediatr. Inst. 13, 133 (1949).
- [5] V. F. Boiko, J. Phys. Chem. USSR 32, 34 (1958).
- [6] V. F. Boiko, J. Inorg. Chem. USSR 2, 422 (1957).

Received April 2, 1958

*Original Russian pagination. See C.B. Translation

ERRATUM

Volume 28, Number 9

Page	Line	Reads	Should read
2577	19	2-Methyl-6-coumarinyl- benzothiazole (VIII).	2-Methyl-6-coumarinyl- benzothiazole (VII).



SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY
ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR.
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosenergoizdat	State Power Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LEIIZhT	Leningrad Power Inst. of Railroad Engineering
LET	Leningrad Elec. Engr. School
LETI	Leningrad Electrotechnical Inst.
LEIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MEP	Ministry of Electrical Industry
MES	Ministry of Electrical Power Plants
MESEP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTI	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.-Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOE	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIEL	Central Scientific Research Elec. Engr. Lab.
TsNIEL-MES	Central Scientific Research Elec. Engr. Lab.—Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIESKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Meteorology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZEI	All-Union Power Correspondence Inst.

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us. — Publisher.





Chemistry Collections IN ENGLISH TRANSLATION

Consultants Bureau's chemistry collections, a unique venture in the translation-publishing field, consist of articles on specialized subjects, selected by specialists in each field, from Soviet chemical journals published in translation by CB. These collections are then presented in symposium form.

Periodically we shall issue new collections taken from the latest volumes of our journals, not only on subjects already covered but also on those which prove most valuable to current scientific research. The following is one of the most recent additions to our list of collections (information on forthcoming titles available on request).

SOVIET RESEARCH IN FUSED SALTS (1956)

42 papers taken from the following Soviet chemistry journals, 1956: Soviet Journal of Atomic Energy; Journal of General Chemistry; Journal of Applied Chemistry; Bulletin of the Academy of Sciences, USSR, Division of Chemical Sciences; Proceedings of the Academy of Sciences, USSR, Chemistry Section. The entire collection consists of one volume, in two sections.

I Systems (23 papers)	\$ 30.00
II Electrochemistry: Aluminum and Magnesium, Corrosion, Theoretical; Thermodynamics; Slags, Mattes (19 papers)	20.00
THE COMPLETE COLLECTION	\$ 40.00

also available in translation . . .

SOVIET RESEARCH IN FUSED SALTS (1949-55)

125 papers taken from the following Soviet chemistry journals, 1949-55: Journal of General Chemistry; Journal of Applied Chemistry; Bulletin of Academy of Sciences, USSR, Div. Chemical Sciences; Journal of Analytical Chemistry. Sections of this collection may be purchased separately as follows:

Structure and Properties (100 papers)	\$110.00
Electrochemistry (8 papers)	20.00
Thermodynamics (6 papers)	15.00
Slags and Mattes (6 papers)	15.00
General (5 papers)	12.50
THE COMPLETE COLLECTION	\$150.00

NOTE: Individual papers from each collection are available at \$7.50 each. Tables of contents sent upon request.

CB collections are translated by bilingual scientists, and include all photographic, diagrammatic and tabular material integral with the text. Reproduction is by multilith process from "cold" type; books are staple bound in durable paper covers.

CONSULTANTS BUREAU, INC.

227 WEST 17TH STREET, NEW YORK 11, N. Y.

PROCEEDINGS OF THE FIRST ALL-UNION CONFERENCE ON RADIATION CHEMISTRY, MOSCOW, 1957

THIS UNPRECEDENTED RUSSIAN CONFERENCE on Radiation Chemistry, held under the auspices of the *Division of Chemical Sciences, Academy of Sciences, USSR* and the *Ministry of Chemical Industry*, aroused the interest of scientists the world over. More than 700 of the Soviet Union's foremost authorities in the field participated and, in all, fifty-six reports were read covering the categories indicated by the titles of the individual volumes listed below. Special attention was also given to radiation sources used in radiation-chemical investigations.

Each report was followed by a general discussion which reflected various points of view in the actual problems of radiation chemistry: in particular, on the *mechanism of the action of radiation on concentrated aqueous solutions*, on the *practical value of radiation galvanic phenomena*, on the *mechanisms of the action of radiation on polymers, etc.*

The entire "Proceedings" may be purchased as a set, or individual volumes may be obtained separately as follows:

Primary Acts in Radiation Chemical Processes
(heavy paper covers; 5 reports, approx. 38 pp., illus., \$25.00)
Radiation Chemistry of Aqueous Solutions
(heavy paper covers, 15 reports, approx. 83 pp., illus., \$50.00)
Radiation Electrochemical Processes
(heavy paper covers, 9 reports, approx. 50 pp., illus., \$15.00)
Effect of Radiation on Materials Involved in Biochemical Processes
(heavy paper covers, 6 reports, approx. 34 pp., illus., \$12.00)
Radiation Chemistry of Simple Organic Systems
(heavy paper covers, 9 reports, approx. 50 pp., illus., \$30.00)
Effect of Radiation on Polymers
(heavy paper covers, 9 reports, approx. 40 pp., illus., \$25.00)
Radiation Sources
(heavy paper covers, 3 reports, approx. 20 pp., illus., \$10.00)

PRICE FOR THE 7-VOLUME SET

: \$125.00

NOTE: Individual reports from each volume available at \$12.50 each. Tables of Contents sent upon request.

CB translations by bilingual scientists include all photographic, diagrammatic, and tabular material integral with the text.

CONSULTANTS BUREAU, INC.

227 WEST 17TH STREET, NEW YORK 11, N. Y.

